STUDY AUTHORITY

The study was conducted under authority of a Pecan Bayou watershed plan authorized by the Flood Control Act of 1968 (Public Law 90-483) approved 13 August 1968. This Act directed "*That the following works of improvement of rivers and harbors and other waterways for navigation, flood control, and other purposes are hereby adopted and authorized to be prosecuted under the direction of the Secretary of the Army and supervision of the Chief of Engineers, in accordance with the plans and subject to the conditions recommended by the Chief of Engineers in the respective reports hereinafter designated. .... PECAN BAYOU, TEXAS .... The project for flood protection on Pecan Bayou, Texas, is hereby authorized substantially in accordance with the recommendations of the Chief of Engineers in House Document Numbered 350, Ninetieth Congress, at an estimated cost of $24,861,000*."

The authorized Pecan Bayou watershed plan contained three units: Pecan Bayou Channel Improvement, Lake Brownwood Modification, and Pecan Bayou Reservoir. The Pecan Bayou Channel Improvement was subsequently de-authorized by House Document 97-59 in June 1981; the Lake Brownwood Modification was de-authorized on November 17, 1986 by the Water Resources Development Act of 1986 (PL 99-662).

In accordance with Federal regulations, Congressionally authorized (General Investigations) water resource studies, are performed in two phases, the reconnaissance and feasibility phases. The purpose of the reconnaissance phase, conducted at a full Federal expense, is to determine if there is a Federal interest in conducting additional detailed studies, determining the scope and cost of the additional studies, and identifying a non-Federal sponsor to participate in the additional studies. Based on the above authority, a reconnaissance study was completed in March 1994. The report determined that Pecan Bayou Reservoir was no longer economically feasible and recommended additional detailed studies for flood damage reduction within the city of Brownwood. Subsequently, a cost-shared feasibility study (shared equally between the Government and the city of Brownwood) was initiated in January 1995.

STUDY PURPOSE

The purpose of this ongoing feasibility study is to investigate water resource problems, needs, and opportunities within the Pecan Bayou watershed, particularly the reduction of flood damages within the city of Brownwood. The feasibility study expands on the preliminary analyses conducted during the reconnaissance study by collecting additional data and completing detailed engineering and technical analyses. The intent is to better define the flood problem, evaluate a wide range of alternatives for flood damage reduction and select from those alternatives which are technically and economically feasible, environmentally acceptable, and supported by the city of Brownwood and the Federal Government, one alternative designated as the recommended plan.

At the point of the selection of the recommended plan, the plan formulation process is essentially complete. The purpose of this document is to present the assumptions, rationale, findings and conclusions of the plan formulation process, and serve as the basis for the feasibility report. Once the plan formulation process has been reviewed and approved, the remaining feasibility study actions will be completed, including detailed engineering and design of the recommended plan.

STUDY PARTICIPANTS

This feasibility study was undertaken as a joint effort between the Fort Worth District, U.S. Army Corps of Engineers and the city of Brownwood. Coordination has been maintained throughout the study with interested Federal, state, regional, and local government officials, the news media, and citizens in the Pecan Bayou Watershed, mainly the City of Brownwood. Existing floodplain information, used in previous Federal Emergency Management Agency studies of cities and counties within the Pecan Bayou Watershed, is aiding these efforts. The U.S. Fish and Wildlife Service was consulted in accordance with the Fish and Wildlife Coordination Act of 1958 (Public Law 85-624), and have provided a Planning Aid Letter analyzing the fish and wildlife problems and needs within the Pecan Bayou Watershed. The Texas State Historic Preservation Officer was also

contacted at the onset of this study. The State Department of Highways and Public Transportation provided bridge profiles and other pertinent information. Contacts were also made with City, County, and State personnel to identify flood prone areas, obtain pertinent data, and discuss viable flood control alternatives. The United States Department of Agriculture, Natural Resource Conservation Service was contacted and aerial photographs of the study area were purchased. Additionally, local real estate companies provided land sale information for the study area.

BASIN AND WATERSHED DESCRIPTION

The Colorado River basin extends from the Lea-Chevez County line in the southeast portion of New Mexico some 600 miles southeasterly across the state of Texas to the Gulf of Mexico near Matagorda, Texas. The basin is bordered to the east and north by the San Bernard and Brazos River basins. The Pecos, Nueces, Guadalupe, and Lavaca River basins border the basin on the west and south. It is about 85 miles wide in the extreme upper portion, increasing to about 170 miles wide near Milburn, Texas. It then decreases to a width of about 30 miles at Austin, Texas, and maintains this width to Columbus. Below Columbus, the watershed width diminishes as the river approaches the Gulf of Mexico. The basin has a total area of 42,344 square miles with the upper portion of the basin lying in the Great Plains. This portion is a flat-semiarid region with numerous closed basins, of which 12,667 square miles do not contribute to the Colorado River drainage. The Colorado River Basin and the location of the Pecan Bayou watershed are shown on Figure 1.

The Pecan Bayou watershed is located in the north-central portion of the Colorado River Basin, near the geographical center of Texas. It is bounded on the north and east by the respective watersheds of the Clear Fork and Leon River tributaries of the Brazos River, and on the west and south by watersheds of small tributaries of the Colorado River. This pear-shaped watershed has an overall length of about 85 miles, a maximum width of about 40 miles, and an average width of about 26 miles. The watershed comprises portions of Taylor, Callahan, Eastland, Runnels, Coleman, Brown, Comanche, and Mills Counties. Major sub-watersheds include the North Prong, Hog Creek, Jim Ned Creek, Salt Creek, Willis Creek, Steppes Creek, Lewis Creek, Dudle Creek, Devils River, MacKinally Creek, Pecan Creek, Long Branch, Fish Creek, Rough Creek, and Blanket Creek. The total Pecan Bayou drainage area is approximately 2,200 square miles. Elevations within the Pecan Bayou watershed range from 2,370 feet (National Geodetic Vertical Datum) at the headwaters of Jim Ned Creek, to 1,150 feet at the confluence with the Colorado River. This is a total drop of 1,220 feet over 154 miles. A map of the Pecan Bayou watershed is shown in Figure 2.

EXISTING FEDERAL WATER RESOURCE PROJECTS

In 1943, the Department of the Army constructed a local flood damage reduction project along Willis and South Willis Creek in Brownwood to mitigate for the adverse hydraulic impacts brought about by the Camp Bowie. The project was constructed in accordance with recommendations made by the Corps of Engineers in the "Supplemental Report on Floods in Willis Creek Valley below Camp Bowie, Texas", dated March 1, 1943. The project consisted of a hydraulic channel improvement on Willis Creek from its confluence with South Willis Creek, upstream a distance of approximately 4,700 feet, a new bridge over South Willis Creek at Fourth Street, and raising and lengthening the existing bridge over Willis Creek at Austin Avenue. In addition, low levees were constructed using spoil material obtained from the channel excavation. The levees were located along the left bank of South Willis Creek from a point about 300 feet above the confluence with Willis Creek to Stephen F. Austin Boulevard, and along the right bank of Willis Creek and South Willis Creek from Austin Avenue to near Third Street. Finally, the abandoned portions of the creek channels were backfilled; several locations of the channel bank were raised to the design water surface elevation, also using the spoil material obtained from the channel excavation.

Hords Creek Reservoir, authorized by the Flood Control Acts of August 18, 1941 and December 22, 1944, is an existing Corps of Engineers project constructed for purposes of flood control, water supply, and recreation. Construction was initiated in January 1947 and the dam was placed in service on June 16, 1948. The Hords Creek Dam is located about 13 stream miles west of Coleman, Texas, and is an earth-filled embankment, which is 6,800 feet long, including an uncontrolled 500-foot-wide broad crested spillway, and water-supply appurtenances consisting of

FIGURE 1 GOES IN HERE

FIGURE 2 GOES IN HERE

an approach channel, intake structure, and a 24-inch water line through the dam. The reservoir has a water surface area of about 510 acres at top of water conservation pool. Total capacity is of 49,290 acre-feet at maximum design water surface, of which 2,860 acre-feet was allocated to sediment storage, 5,780 acre-feet to water conservation storage, 16,670 acre-feet to flood control storage, and 23,980 acre-feet to surcharge storage.

The U.S. Department of Agriculture Natural Resource Conservation Service (NRCS) has an on-going flood-detention-reservoir program on the Pecan Bayou watershed. The program is outlined in the Report of the U. S. Study Commission - Texas, dated March 1962, and includes 146 floodwater retarding structures, of which 88 reservoirs are located upstream of Lake Brownwood and 58 downstream. Associated with this program the NRCS has prepared definite work plans for construction of 55 additional reservoirs upstream from Lake Brownwood.

Pecan Bayou Lake was authorized by the Flood Control Act of 1968 (Public Law 90-483) approved 13 August 1968. The project would provide flood damage reduction, water supply, and recreation. The authorized project consists of an earth filled dam 15,500 feet in length (including the spillway), a top width of 20 feet, and a maximum height of 107 feet. The spillway was broad-crested and uncontrolled. In 1978, the Brown County Water Improvement District Number 1 (BCWID#1), requested the Corps of Engineers to initiate Phase I Advance Engineering and Design Studies, on the Pecan Bayou Lake. However, the studies were not funded and no further contact was made until 1984 when the BCWID#1 was notified of the possible deauthorization of the project. The BCWID#1 passed a resolution on 9 July 1985, again requesting the Corps of Engineers to initiate Phase I Advance Engineering and Design Study on Pecan Bayou Lake. Again, the studies were not funded. In a 1994 Reconnaissance Study, it was determined that the Pecan Lake Bayou project was no longer economically feasible, although the project remains authorized for construction.

The Pecan Bayou Channel Improvement, Brownwood, was also authorized by the Flood Control Act of 1968 (Public Law 90-483), approved 13 August 1968. The authorized project consisted of 7.3 miles of channel improvement, having a bottom width of 300 feet, and a depth of 32 feet. Local interests did not wish to further participate in the development of this project. Subsequently, the project was de-authorized by House Document 97-59, dated 9 June 1981.

The Lake Brownwood Modification project was also authorized by the Flood Control Act of 1968 (Public Law 90-483) approved 13 August 1968. The project consisted of extending the existing embankment (Lake Brownwood was constructed in 1932 by local interests), lengthening the existing concrete spillway, and modifying the existing outlet structures. The detailed design was initiated and several Design Memoranda were published in 1976. However, in 1976, the Corps of Engineers determined that the project was a local dam safety issue and not a flood control project of Federal interest. The BCWID#1 constructed the modification in 1981 substantially in accordance with the Design Memoranda mentioned above. Subsequently, the Lake Brownwood Modification project was de-authorized by Public Law 99-662, dated 17 November 1986.

EXISTING NON-FEDERAL WATER RESOURCE PROJECTS

Lake Brownwood is impounded by a dam on Pecan Bayou, a short distance below the confluence of Pecan Bayou and Jim Ned Creek. The drainage area above the dam is about 1,544 square miles. The original dam was completed in 1932. Lake Brownwood provides municipal and agricultural water supply, flood damage reduction, and recreational opportunities and is operated by the BCWID#1. The dam is an earth-fill embankment about 1,580 feet long. Its maximum height is about 140 feet and it has a crown width of 12 feet. The embankment includes: two 42-inch conduits through the base of the dam near the center for drawing down the reservoir during emergencies, and a conduit near the south end of the dam for releasing water into the supply system. An uncontrolled spillway is located in a saddle about 2,000 feet north of the dam and consists of a cut through the saddle. The spillway has a width of about 479 feet. The total storage below the conservation level is about 119,000 acre-feet. The BCWID#1 has had to make major repairs on the conduits and conduit-gate structure and does not now utilize the existing Broome gates at the intake ends of the 9-foot conduits. Instead, BCWID uses the 24-

inch outlets, which bypass the Broome gates, for regulating the lake level. The reduction in discharging capacity of the outlet results in more frequent use of the existing spillway.

The principal purpose of Lake Brownwood is water supply in providing water for the cities of Brownwood, Bangs, Santa Anna, and Early for municipal and industrial purposes and water supply for irrigating about 5,000 acres of arable land within the boundaries of the District. The BCWID#1 comprises about 14,000 acres of land within its boundaries, including the urban area of the city of Brownwood. In addition to serving about 5,000 acres of arable land within the District boundaries, the District, at times, sells water to irrigate portions of about 1,500 acres outside the District boundaries.

Lake Coleman is located on Jim Ned Creek and was constructed by the city of Coleman for municipal and industrial water supply. Construction was initiated in August 1965, completed in April 1966, and put into operation in May 1966. The storage capacity at the time of construction was 40,000 acre-feet. Lake Coleman, which is served by a drainage area of about 305 square miles, provides the majority of the water supply for the city of Coleman. Lake Coleman has a normal water surface area of about 2,000 acres.

Lake Clyde is located on North Prong Pecan Bayou, a tributary of Pecan Bayou, about 6 miles southeast of the city of Clyde. The reservoir was designed for municipal water supply and floodwater detention. Construction of the dam was initiated in June 1969 and completed in November 1969. The storage capacity at time of construction was 5,750 acre-feet. Lake Clyde is the primary source of water supply for the city of Clyde.

Lake Scarborough is located on Indian Creek, a tributary of Jim Ned Creek, about 4 miles north of the city of Coleman. The reservoir, completed in 1927, was constructed by the city of Coleman for municipal water supply. The storage capacity at time of construction was 2,000 acre-feet. The water from Lake Scarborough is filtered, and then delivered to Coleman through a 10-inch pipeline. Lake Scarborough, which is served by a drainage area of about 12 square miles, provides a negligible amount of water supply, and proved to be inadequate for the water supply needs of the Coleman area. Thus, the city of Coleman acquired the water supply storage rights in the Hords Creek Reservoir project prior to its construction.

PREVIOUS WATER RESOURCE STUDIES AND REPORTS

PREVIOUS CORPS WATER RESOURCE STUDIES AND REPORTS

There are numerous technical reports published that document water resources investigations made within the Pecan Bayou watershed. The following paragraphs describe, in chronological order, prior Corps of Engineers studies and reports within the Pecan Bayou watershed.

1. **Report From the Chief of Engineers on Preliminary Examination of Colorado River, Texas, with a View to the Control of its Floods, April 3, 1930 (House Document No. 361, 71st Congress, 2nd Session).** This report was a preliminary examination of the Colorado River for flood control as authorized by the acts of May 21, 1924 and February 12, 1929. This report investigated various dams and potential dam sites; however, it recommended that due to the lack of existing or prospective navigation on the river that there was no Federal interest in flood control. Additionally, the potential Federal interest in flood control was investigated and determined that the state should be responsible for all flood control activities.

2. **Report on Survey of Pecan Bayou, Texas, for Flood Control and Allied Purposes, March 1939 (House Document No. 370, 76th Congress, 1st Session).** This report recommended a plan of improvement that included the construction of Hords Creek Lake on Hords Creek above the city of Coleman and enlargement of the existing Lake Brownwood on Pecan Bayou. Construction of Hords Creek Lake and enlargement of Lake Brownwood were authorized by the Flood Control Acts of 18 August 1941 and 22 December 1944. The Hords Creek Lake project was constructed and became operational during April 1948.

3. **Definite Project Report on Hords Creek Reservoir, Hords Creek near Coleman, Texas, Colorado River Basin, February 1946.** This report presents the definite project plan for Hords Creek Reservoir on Hords Creek near Coleman, Texas, authorized by the Flood Control Act, approved August 18, 1942 (Public Law 228, Seventy-seventh Congress, first session). The project plan detailed the construction of a multiple purpose dam and reservoir, principally for flood control and water conservation. The estimated first cost was $1,479,000 with an annual operation and maintenance cost of $11,000.

4. **Review of Reports - 1948 (Unofficial)**. Subsequent to the 1939 Report on Survey, a second rep*ort entitled "Review of Reports on Pecan Bayou, Texas, Flood Protection, Brownwood, Texas," dated 3 September 1948, was prepared. This report suggested a restudy of the authorized Lake Brownwood enlargement, along with studies of alternate reservoir and channel improvement plans. This report was submitted to the Office of the Chief of Engineers and the Board for Rivers and Harbors, but was returned to the district for further revision in 1954.

5. **The Master Plan for Recreation and Land Use, Hords Creek Dam and Reservoir, near Coleman, Texas, May 1950.** This report recommends recreational facilities to be constructed at the project to accommodate the large numbers of visitors to the lake and adjacent lands. These proposed facilities were to be located on Government owned lands. Additionally, this report requested that authority for the development of these recreational facilities be approved at an early date.

6. **Review of Reports on Pecan Bayou Watershed, Colorado River Basin, Texas - October 1963.** This report investigated flooding problems along Pecan Bayou, Willis Creek, Adams Branch, and Lake Brownwood. The report recommends improvements to the Lake Brownwood and surrounding creeks, and construction of two upstream reservoirs. The channel improvements had a first cost of $11,281,000. The improvements to Lake Brownwood consisted of enlarging both the dam and reservoir at a first cost of $3,060,000. The upstream reservoirs were recommended to be multi-purpose and designated as Pecan Bayou and Coleman. The first cost of the reservoirs was $22,410,000. Neither of these projects has been constructed.

7. **House Document Number 350, 90th Congress, 2nd Session, July 8, 1968, Pecan Bayou, Texas.** This house document and subsequent act (Public Law 90-483, August 13, 1968) authorized a study in Pecan Bayou, Texas. Subsequent to the completion of the Pecan Bayou Watershed Report, a letter from the Texas Water Development Board (dated August 12, 1966) indicated that local interests had constructed a dam and reservoir on Jim Ned Creek in the general location of the proposed Coleman reservoir. Additionally, the Soil Conservation Service (letter dated April 24, 1967) was working on detailed planning for a watershed work plan (Brownwood Laterals) for Willis Creek and Adams Branch in the city of Brownwood. Therefore, these portions of the watershed plan were deleted from the requested authorization. The authorized plan of improvement included the Lake Brownwood modification, the construction of Pecan Bayou reservoir, and/or Pecan Bayou channel improvements.

8. **Lake Brownwood Modification, Pecan Bayou, Colorado River Basin, Texas, Design Memorandum Number 1, General, Phase I - Plan Formulation, April 1975.** This report recommended construction of the Lake Brownwood modifications. This modification would ensure the continued existence of Lake Brownwood for needed flood control, water supply, and recreation in the Pecan Bayou watershed. The plan included construction of a new dam, immediately downstream of the existing Lake Brownwood dam, and erosion control measures to prevent erosion of the existing spillway. The first cost of this project was estimated to be $21,295,000.

9. **Revised Plan of Study, Feasibility Report for Water Resources Development, Colorado River and Tributaries, Texas, Colorado River Basin, Texas, June 1975.** This report presented an amended plan of study to update the Revised Plan of Survey for Comprehensive Survey Report of the Colorado River and Tributaries, Texas, dated August 1963.

10. **Navigability Study, Colorado River, Tributaries and Lakes, Colorado River Basin, Texas (River Mile 290.1 to 890.0), February 1975.** This report determined that as of 10 February

1975, the Colorado River from river mile 291.6 to 890.0, Texas Highland Lakes and other lakes above river mile 290.1 and all tributaries of the Colorado River above river mile 290.1, together with lakes thereon, are non-navigable. This report also recommended that this portion of the Colorado River (river mile 290.1 to 890.0), Texas Highland Lakes and other lakes above river mile 290.1 and all tributaries of the Colorado River above river mile 290.1, together with lakes thereon, be declared non-navigable waters.

11. **Lake Brownwood Modification, Pecan Bayou, Colorado River Basin, Texas, Design Memorandum Number 1, General, Phase II - Project Design, June 1976**. This report finalized the design of the Lake Brownwood modifications. This modification would ensure the continued existence of Lake Brownwood for needed flood control, water supply, and recreation in the Pecan Bayou watershed. The plan was changed to an "add-on" or composite embankment rather than a new dam immediately downstream of the existing Lake Brownwood dam. The erosion control measures for the existing spillway were finalized. The first cost of this project was estimated to be $24,850,400.

12. **Lake Brownwood Modification, Pecan Bayou, Colorado River Basin, Texas, Design Memorandum Number 4, Availability of Construction Materials, June 1976**. This report presents the authoritative information and the results of investigations and study regarding the availability and economics of satisfactory sources of major construction materials required for construction of Lake Brownwood modification and its appurtenant structures.

13. **Lake Brownwood Modification, Pecan Bayou, Colorado River Basin, Texas, Design Memorandum Number 5, Real Estate - Lands For Construction Area, July 1976**. This report presents the location, general description, land utilization, acquisition criteria, and schedule of acquisition encompassing approximately 399 acres of the construction area. The proposed real property acquisition line considers requirements for construction of the project and the comparable sales, trends of values, relocation assistance and estimated costs for acquisition of the land and interests.

14. **A Final Supplement to the Final Environmental Impact Statement, Lake Brownwood Modification, Pecan Bayou Watershed, Colorado River Basin, Texas - March 1977.** This supplement to the EIS determined that the project would have some degradation of the water quality immediately downstream, due to construction activities. There would be a loss of wildlife habitat within the construction area, and a loss of 383 acres of cropland, which would be used as fill material for the embankment. Nine identified archeological and historic sites would be avoided during the construction.

15. **Status Report - Colorado River Basin, Texas - September 1987.** This report presents the results of preliminary investigations to identify water resource problems and needs in the basin. This work was accomplished under authority of the Colorado River Basin, Texas, basin wide authority.

16. **The Texas Statewide Inventory of Flood Protection Needs - May 1990**. This study was completed to provide an up-to-date, community-specific inventory of flooding problems and solutions for 756 cities and towns in Texas that could be incorporated into the revised state water plan. This inventory contains data from previous planning studies and National Flood Insurance Program (NFIP).

17. **Report on Flooding, April - May 1990.** This report provides a summary of the flood damages experienced and effectiveness of U.S. Army Corps of Engineers projects during the period of April-May 1990. This report contains general information on the storms and their resultant impacts. The report contains a brief description of the rainfall and various river basins that experienced flood inundation, flood losses sustained in the respective counties and cities, and estimates of damages prevented by existing Corps of Engineers projects.

18. **Reconnaissance Report – Pecan Bayou Lake, Colorado River Basin, Texas – March 1994.** This report documented a significant need for flood protection within the Pecan Bayou watershed study area, particularly within the city of Brownwood along Pecan Bayou and Willis Creek. Seven preliminary alternatives were investigated including three different detention

structures, three hydraulic channel improvements, and a non-structural alternative (permanent evacuation). Two economically viable flood damage reduction plans were identified and recommended for further study. This document is the result of that study recommendation.

PREVIOUS NON-CORPS STUDIES AND REPORTS

There are numerous other technical reports published by other Federal, state, regional, and local entities that document water resources investigations made within the Pecan Bayou watershed. The following paragraphs briefly describe these studies and reports.

1. **Federal Emergency Management Agency (FEMA).** FEMA is responsible for the administration of the National Flood Insurance Program. A few cities and counties within the Pecan Bayou watershed are participants in the program. The results of the studies are shown in the flood insurance rate maps (FIRMs) published by FEMA. The following is a list of known Flood Insurance Studies completed (effective program date) within the Pecan Bayou watershed. Town of Blanket (April 2, 1992), City of Brownwood (July 6, 1982), City of Clyde (May 25, 1978), City of Coleman (April 1, 1981), Town of Cross Plains (Not in Program), City of Early (July 1, 1987), Town of Mullin (Not in Program), City of Novice (Not in Program), Brown County (March 1, 1991), Callahan County (Not in Program), Coleman County (Not in Program), Comanche County (June 20, 1990), Eastland County (Not in Program), Runnels County (Not in Program), Mills County (April 28, 1992), Taylor County (June 1, 1987).

2. **The Report of the U.S. Study Commission - Texas, The Eight Basins, March 1962**. An act of Congress, approved 28 August 1958, established the United States Study Commission on the Nueces, Trinity, Brazos, Colorado, Guadalupe, San Antonio, Nueces, and San Jacinto River Basins and intervening areas within the state of Texas. The directive instructed the Commission to make an integrated and cooperative investigation, study, and survey in connection with and in promotion of the conservation, utilization, and development of the land and water resources. The purpose is to formulate a comprehensive development plan for submission to and consideration by the President and the Congress. The report evaluated the water conservation requirements and means of satisfying them to the year 2010. However, due to the use of generalized procedures and criteria or the total lack of economic analysis of certain multiple purposes, the plan did not adequately evaluate flood control, navigation, hurricane protection, and pollution abatement. The plan was a well-conceived framework from which the ultimate objectives of comprehensive and integrated water and land resource development could be obtained. It is considered a flexible base subject to refinement and revision as prevailing conditions dictate and as more detailed analyses are made.

3. **Department of the Interior, Reservoir Operation in Texas - June 1985.** This report, authorized by the Water Resource Development Act of 1978 (PL 95-467), compiled a comprehensive listing of the water resources and their uses within the various river basins in the state of Texas. This report summarizes the reservoirs, their storage, and operating plans.

4. **Department of Water Resources, Texas, Water For Texas - November 1984.** A two-volume report was prepared. Volume 1, A Comprehensive Plan for the Future, of the amended 1969 Texas Water Plan is an executive summary that sets forth planned actions and policy recommendations. Volume 2, Technical Appendix, is a technical document which provides details of current water development and use, projected future water supply and treatment needs, and potentially developable water supplies to meet future water needs in each river and coastal basin of the state.

5. **Texas Water Development Board, Occurrence and Quality of Ground Water in Brown County Report Number 46, May 1967.** This report was prepared in response to a directive from the Texas Water Pollution Control Board and evaluated the ground water in Brown County to determine what, if any, pollution was occurring. This was accomplished by collecting and compiling information regarding the occurrence and chemical quality of the ground water used by landowners and others. Additionally, this study identified and delineated the underground formations containing useable water.

6. **Texas Water Development Board, The Texas Water Plan, November 1968.** This report outlines a flexible guide for the orderly development, conservation, and wise management of the State's water resources to meet the needs of the state to the year 2020. The plan suggests the possibility of importing large quantities of surplus water from the lower reaches of the Mississippi River to areas of greatest need in Texas.

7. **Texas Water Development Board, Water For Texas, Today and Tomorrow, December 1990.** This report updates and presents the 50-year plan for the state of Texas, including the current and prospective water uses, identifies water supplies, and estimates facility needs and costs. The plan also describes water problems and opportunities, outlines significant environmental concerns and water issues, and offers program and policy recommendations.

8. **Texas Water Development Board, Water For Texas, Today and Tomorrow, November 19, 1992.** This report updates the 50-year plan for the state of Texas. This summary document provides details on the current and prospective water uses, identifies water supplies, and estimates facility needs and costs. The plan also describes water problems and opportunities, outlines significant environmental concerns and water issues, and offers program and policy recommendations. Additionally, the document outlines proposed future Texas Water Development Board actions and key policy recommendations to local, State, and Federal entities in the area of water management.

9. **Texas Water Commission, A Plan For Meeting the 1980 Water Requirements For Texas - 1961**. This report addressed potential flood damages and water supply issues. Pertinent data to the Pecan Bayou watershed included discussion of a reservoir on Jim Ned Creek at the Jim Ned Creek site.

10. **Texas Water Commission, The State of Texas Water Quality Inventory, August 1992.** This report was prepared in accordance with Section 305(b) of the Clean Water Act and describes the status of the state waters based on the most recent four years of monitored surface and ground water quality data. An overview is provided discussing water quality trends, attainment of surface water quality standards, relative impacts of pollutants from various sources, and water bodies where additional actions are needed. Surface water quality data is summarized for individual streams, river, reservoir, bay, estuary and Gulf of Mexico segment. Groundwater quality within each major river basin is described.

11. **Brown County Water Improvement District Number One, Hydrologic Study of Lake Brownwood and the Pecan Bayou Watershed, March 1965**. This study investigated the current and likely future dependable yield from Lake Brownwood.

12. **Brown County Water Improvement District Number 1, November 1979, Investigation of Lake Brownwood Dam.** This study analyzed the adequacy of the existing dam. The study concluded the foundation of the existing dam appears to be stable, and the spillway does not appear to be in immediate need of rehabilitation. The study further concluded the existing dam is hydraulically inadequate for the design storm. Their recommendations included raising the dam to elevation 1470' (from existing elevation 1449'), and a modification to the outlet works to allow for water supply by pipeline. Modifications to the spillway were not warranted at that time.

STUDY AREA

Based on the problems and opportunities identified in the March 1994 Reconnaissance Report, flooding has been a reoccurring concern within the Pecan Bayou watershed, particularly along Pecan Bayou and Willis Creek in the city of Brownwood. The following is a physical description of the Pecan Bayou and Willis Creek study areas as seen in Figures 3 and 4 for purposes of this feasibility study. It has been refined on the basis of the reconnaissance findings and the willingness of the local sponsor.

Pecan Bayou

The study area is defined as the approximate 500-year flood plain along Pecan Bayou from a point approximately 2,000-feet upstream of U.S. Highway 377, extending downstream to FM 2129, about 5,000 feet downstream of the confluence with Willis Creek, a distance of approximately 22,000-feet. Within the study area, Pecan Bayou is a gently, to a moderately, meandering waterway having a top width ranging between 135- to 215-feet and depths between 22- and 32-feet. The slope is estimated to drop 0.53 feet per thousand foot (2.8 feet per mile) of channel. About 500-feet upstream of U.S. Highway 377, a concrete structure is located across the bayou, and produces a permanent pool of water for the adjacent Riverside Park. Pecan Bayou flows in a south-southeasterly direction through the eastern portion of the city of Brownwood in the study area, and is bounded by FM 2525 (Williams Ranch Road) to the north and Atchison Topeka and Santa Fe Railroad to the south. In addition to U.S. Highway 377 near the upstream study area limit, there are two bridges crossing Pecan Bayou: Woodson Road and the Atchison Topeka and Santa Fe Railroad. The majority of the development is located in the upstream portion of the study area.

Willis Creek

Willis Creek originates about five miles southwest of Brownwood and flows generally north and then east, passing through the southern portion of Brownwood, to its confluence with Pecan Bayou southeast of the city. The watershed has a drainage area of 28.4 square miles. The study area is defined as the Standard Project Flood Plain along Willis Creek beginning at its confluence with Pecan Bayou and extending upstream a distance of about 24,000 feet terminating near Asbury Street. Within the study area, Willis Creek is a gently, to a moderately, meandering waterway having a top width ranging between 40- to 135-feet and depths between 4- and 11-feet. The slope is estimated to drop 2.92 feet per thousand foot (15 feet per mile) of channel. Willis Creek flows in an easterly direction through the southern portion of the city of Brownwood to the confluence with Pecan Bayou. Willis Creek has 3 concrete box culverts, at Austin Street, 4th Street, and 14th Street. Located further upstream is a wooden railroad bridge and an arched rock culvert bridge at Crockett Drive. The majority of the study area is bordered on at least one side by residential development. Figure 4 displays the Willis Creek study area.

A principal tributary to Willis Creek is South Willis Creek. South Willis Creek originates a few miles due south of Brownwood and proceeds in a northerly direction to NRCS floodwater retarding site "Brownwood Laterals #4A", at which point the total drainage area is 0.84 square miles. Below the damsite, it proceeds in a northerly direction to its confluence with Willis Creek. Another prominent feature of this watershed is the NRCS floodwater retarding site "Brownwood Laterals #4B", which is situated on the "Country Club" tributary. South Willis Creek has a drainage area of 10.7 square miles.

DESCRIPTION OF THE WATERSHED AND STUDY AREA

History

North American Indians were the first inhabitants of Brown County. The first white men can be traced back to the early 1700's when Spanish missionaries and soldiers inhabited the area. The first Anglo-Americans to enter the county were under the leadership of Captain Henry Stephenson Brown in 1828 seeking to recover livestock stolen by Indians. Within ten years, land surveyors came into the county running landlines and staking corners for citizens of Texas who lived in the eastern and southeastern sections of the state. Brown County was established in 1865 by the state legislature. The City of Brownwood was created on August 27, 1856 and organized on March 21, 1857. The original city was located approximately one mile east of the present location on the banks of Pecan Bayou and moved to its' present location in 1867. Brown County remained a frontier settlement for twenty years following the coming of the first settlers. The settlers made their homes in the valleys near the streams. There were no towns other than the county seat and it was a primitive frontier village. A land boom, precipitated by increasing land prices

FIGURE 3 GOES IN HERE

speculation and the extension of the Sante Fe Railroad into Brownwood, brought an increase in the population and gave added impetus to the agricultural economy of Brownwood and surrounding areas. Between 1880 to 1900, the open range of Brown County was converted to farmland. By 1920, Brownwood was the largest cotton-buying center west of Fort Worth. During the 1920's, there was an oil boom in the area resulting in even greater economic growth. In September 1940, Brownwood was selected as the site for a training center for the U.S. Army. The original military campsite of 2,000 acres expanded to include nearly 5,000 acres, and the original area of 60,000 acres expanded to nearly 122,000 acres. By March 1941, the population of Brownwood has risen to 23,500, up from 14,000 the previous year.

Climatology and Precipitation

The Pecan Bayou watershed has a temperate climate characterized by hot summers and cool winters. Freezing temperatures and snowfall are occasionally experienced during the passage of cold high-pressure air masses from the northwestern polar regions and the continental western highlands. The mean annual temperature in the watershed is about 65 degrees (F). Temperatures range from a maximum of 114 degrees to a minimum of minus 6 degrees. January has an average minimum daily temperature of about 32 degrees. August, the warmest month, has an average maximum daily temperature of about 97 degrees. The average length of the growing season between killing frosts is about 247 days.

The storms that cause precipitation in the Pecan Bayou watershed are of three general types: thunderstorms, frontal storms, and tropical storms originating in the Gulf of Mexico. Most of the precipitation in the basin results from storms of the first two types, although the tropical type storms occur frequently, primarily during the period June to November. The mean annual precipitation over the Pecan Bayou watershed is about 27 inches and varies from about 23 inches in the headwaters region to about 29 inches near the mouth. Snowfall is an insignificant portion of the total precipitation, except for a few exceptionally heavy snowfalls (such as the eight-inch fall in February 1966). Annual precipitation recorded at Brownwood has varied from a maximum of 46.00 inches in 1919 (although in 1990 the total rainfall of the area was 45.97 inches) to a minimum of 10.86 inches in 1921. The normal seasonal distribution of rainfall over the watershed is generally favorable for agricultural purposes. Daily precipitation extremes include 11.49 inches, on 26 April 1990; 6.60 inches, on 5 October 1959; and 5.90 inches, on 1 June 1988. The maximum calendar month precipitation was 14.66 inches in April 1990, closely followed by the 12.90 inches in June 1959.

Physiography and Geology

The Pecan Bayou watershed lies principally within the Central Texas section of the Osage Plains Section of the Central Lowlands Physiography province. The watershed portions that are upstream and downstream from approximately the Brown-Coleman County line are principally within the Rolling Plains and the North Central Prairies land resource areas, respectively. The watershed is characterized by plateaus in maturity and later stages of erosion with areas of well-developed and rapid drainage and moderate relief, ranging from relatively smooth plains to sharply eroded valleys. The watershed soils are sandy loams, clay loams, clays, and stony soils, ranging from slightly acid to neutral to slightly calcareous, and from dark brown to reddish brown to grayish brown. The soils within the mainstream valleys are alluvial deposits. The watershed elevations vary from about 2,370 feet above mean sea level (along the headwater divide, about fourteen miles south of Abilene**)**, to about 1,150 feet above mean sea level (at the confluence of Pecan Bayou with the Colorado River, about eight miles west of Goldthwaite). Limestones, shales, sandstones, and conglomerates of Pennsylvanian, Permian, and Lower Cretaceous ages underlie the watershed. The Pennsylvanian age stratum regionally dips toward the west-northwest at a rate of about 60 feet per mile. Although small faults and flexures are common in the Pennsylvanian strata, geologic maps prepared by the Texas Bureau of Economic Geology, and other structural geology maps reviewed during the study, do not

FIGURE 4 GOES IN HERE

delineate any significant faults in the study area. Brownwood lies within seismic zone 0, according to the Uniform Building Code Seismic Zone Map, as presented in EM 1110-2-1806, dated 31 July 1995, subject: Earthquake Design and Evaluation for Civil Works Projects.

A geotechnical field investigation and laboratory testing of soil and rock samples collected from borings drilled along Pecan Bayou and Willis Creek in the study area was completed. Alluvial deposits consisting of silt clays (CL to CH) and sands (SP-SM) were identified in borings drilled along Pecan Bayou. Alluvial deposits consisting of clays (CH), sandy clays (CL), clayey sands (SC), and sandy, clayey gravels were identified in borings drilled along the Willis Creek. The primary materials in the area of Willis Creek are soft shales and hard limestone of the Pennsylvanian age Strawn Group. Some borings drilled along Willis Creek identified rock at depths as shallow as 2 to 2.5 feet below ground surface, whereas other borings encountered alluvial deposits to depths of 17.8 to 20 feet (total depth drilled). It is anticipated that any excavation along Willis Creek would encounter significant quantities of rock.

Wildlife And Aquatic Resources

The Pecan Bayou watershed is situated in the West Cross-Timbers vegetational region, which is characterized by rolling to hilly topography with moderate relief from relatively smooth plains to sharply eroded valleys. Surface drainage is rapid. Mesquite/oak woodlands and short to mid-height grasses occur on the slopes and hilltops, with denser stands of oak, elm, hackberry, ash, and pecan at the lower elevations along local drainages. Agricultural fields and pasture are intermingled with undeveloped land. A wide range of wildlife inhabits the watershed, including game and non-game mammals, birds such as raptors, waterfowl, wading birds, shorebirds, perching and songbirds, reptiles and amphibians. Overhanging tree limbs and woody debris in the bayou provides good fish habitat. The bayou contains deep and shallow water areas that support a variety of fish species.

The portion of Pecan Bayou within the city of Brownwood downstream of U.S Highway 377 varies in width from 40 to 60 feet, and the water depth typically varies from several feet to very shallow. Tree species along the Pecan Bayou include pecan, live oak, elm, willow, red mulberry, and hackberry. The understory includes greenbriar, trumpet creeper, and immature tree species. Portions of the banks of Pecan Bayou are heavily wooded with large pecan trees. This band of riparian habitat provides an important corridor that is utilized by deer, raccoons, squirrels, and other mammals, and a wide variety of birds, including raptors, waterfowl, shorebirds, and songbirds. Portions of Pecan Bayou are heavily eroded, with tree roots and exposed soil. Trees that have fallen into the stream trap debris and create deeper pools of slow moving water. Riffle and run complexes also occur in areas where the Bayou narrows. These areas constitute special aquatic sites of high habitat quality. There are also overhanging tree limbs providing shade, and woody debris along the waterway that provides basking sites for turtles and snakes. The aquatic habitat appears to be high quality for fish, amphibians, and reptiles. No vegetated wetlands are known to be in this area. In some areas, the riparian has been cleared to the stream bank for agricultural and limited commercial development.

The trees along this corridor of Willis Creek include large, mature live oaks, red oaks, pecans, willows, hackberries, and elms. The overstory provides considerable shade for the creek. The developed areas along the creek have very little or no understory. The undeveloped areas and creek banks are vegetated with dense patches of greenbriar, honeysuckle, and sapling willows, oaks, pecans, live oak, elms, and hackberry. Although in an area of urban development, the riparian corridor of Willis Creek provides important habitat. The wildlife species present are generally limited to those tolerant of relatively high levels of human disturbance. These include mammals such as raccoons, opossums, fox squirrels, and small rodents. Numerous species of reptiles and amphibians are also present. Bird species range from the red-tailed hawk to various perching and songbirds such as chickadees, warblers, and sparrows. Several species of duck have also been observed utilizing Willis Creek. Willis Creek experiences seasonal high and low flows and

contains many larger pools along the watercourse. These larger pools play an integral part in the survival of many species during periods of low flows by providing a reliable water source and can also sustain fish year round. No vegetated wetlands were discovered in the study area.

Threatened and Endangered Species

According to the U. S. Fish and Wildlife Service, the following species are listed as either threatened or endangered within the Pecan Bayou watershed. They are the threatened Concho Water Snake (*Nerodia paucimaculata*), and the endangered Black-capped vireo (*Vireo atricapillus).* No black-capped vireo habitat is known to occur along Pecan Bayou. The Concho Water Snake Recovery Plan (Fish and Wildlife Service 1993) indicates populations appear to be fairly continuous to about the FM 45 Bridge upstream from the mouth of Pecan Bayou. However, no Concho Water Snakes have been found in Pecan Bayou study area. Any recommended plan within the study area is not anticipated to affect any Federally listed threatened or endangered species.

Cultural Resources

The cultural resources work for the Pecan Bayou study was conducted in accordance with and partial fulfillment of the U.S. Army Corps of Engineers obligations under the National Historic Preservation Act Of 1966 as amended (PL 89-665). Other obligations include the Archeological And Historical Preservation Act Of 1974, as amended (PL 90-190), and Executive Order no. 11593 the "Protection And Enhancement Of The Cultural Environment".

The study area is an erosional plateau of Cretaceous sandstone and sandy outcrop with ridges oriented in a north-south direction. Most of the lowlands are erosional except for the "mesquite flats" which lie in depositional areas. Prehistorically it was a savannah with timber along the streams. The land was probably overgrazed, resulting in the uplands growing cactus, mesquite, and scrub oaks. Soils in the project area are Frio, Rochelle, and Callahan-Throck. Frio is a deep, nearly level soil on floodplains along major streams. Rochelle is a deep, gently sloping soil found in the uplands. The Callahan-Throck association consists of stony, moderately deep and deep soils on uplands.

No systematic archeological or structural inventories have been completed within the study area as part of this feasibility study. A number of small archeological surveys near the confluence of Willis Creek and Pecan Bayou were completed in 1978 and 1980 by local archeologists. Eight archeological properties on Willis Creek and Pecan Bayou near their confluence just downstream of the Brownwood water treatment plant were recorded (publication unknown). In 1987, the Travis County Archeological Society recorded six additional archeological properties, two of which were historic period cemeteries (no publication). Previous efforts on other portions of Pecan Bayou have recorded numerous archeological properties and several historic buildings and structures. Discovered in the area west of the Willis Creek study area were two burned rock middens, a human burial associated with a rockshelter destroyed during highway construction in Brownwood, and the testing of several sites on a tributary of the Pecan Bayou. A single site has been recorded south of the Willis Creek study area along a small tributary leading to Willis Creek. A portion of the middle and all of the lower portions of the study area is likely to contain buried archeological resources. A proper assessment of the potential for buried archeological resources will require a systematic investigations using primarily heavy mechanical equipment to conduct trenching investigations. Systematic shovel testing will also be employed as appropriate to specific areas. All inventory and survey efforts will be required during the plans and specification phase and prior to construction in order to limit project redesign, realignments, or costly mitigation efforts.

Water Quality

The most recent surface water quality survey completed by the state of Texas indicates that water quality problems associated with elevated levels of inorganic nitrogen,

phosphorous, and fecal coliform have been measured on Pecan Bayou in the area downstream of the confluence of Willis Creek to the Colorado River. The presence of this material is likely influenced by the Brownwood wastewater treatment facility. There are no known water quality problems identified in Pecan Bayou upstream of Willis Creek.

In January 1994, a raw sewage spill occurred resulting in a large fish kill in Pecan Bayou. The County Health Department issued a warning not to consume fish caught from the two streams. Water samples taken at the site contained ammonia up to 6 mg/L (anything over 3 mg/L can be toxic). Additionally, the dissolved oxygen was 0.7 mg/L.

Groundwater in Brown County is located in shallow and discontinuous, low permeability zones of sandstone and limestone in all Cretaceous, Permian, Pennsylvanian and Ordovician groups. Additional occurrence of groundwater is in the terrace and floodplain alluvium of Pecan Bayou. The alluvial zones are in hydraulic connection with the stream, its major tributaries, and large lakes. The source of water in the alluvial aquifer is chiefly the infiltration of rainfall on the surface of the alluvium. Most measured water levels in floodplain wells range from 13 to 41 feet. It is anticipated that during dry periods Pecan Bayou acts as a means for groundwater discharge into the river with the opposite being true for wet periods. Under natural conditions, most of the alluvial groundwater is discharged into surface water bodies, evaporated, or transpired. During periods of high river stage, ground water that normally seeps into the river is backed up in the alluvium, and a large part goes into riverbank storage along with some of the floodwater. Water levels in the alluvium rise during these periods, particularly near the river. When the river stage declines, groundwater again discharges into the river, and the water levels decline.

Reports of oil-field brine contamination (excessive concentrations of sodium, chloride, magnesium, and calcium) of groundwater have been documented in the past. The sources of contamination have most likely resulted from overflow of surface pits, discharging wells, and leaking oil-field waste lines.

Hazardous, Toxic, and Radiological Wastes (HTRW)

An initial assessment was performed within the study area. Reviews of the regulatory records, aerial photographs, and interviews indicated that the area has been historically commercial and agricultural in nature. In recent years there has been light residential development south and more extensive residential development north of the study area.

The observed water clarity during a visual inspection of Willis Creek during a low runoff period appeared to range from stained in upper reaches to quite murky in the lower reaches. Visual inspection of Pecan Bayou revealed a general murkiness throughout its extent. Possible hazardous, toxic, or radioactive wastes noted during the site inspection consisted of the presence of numerous 55-gallon drums behind the 3M Company facility. The visual survey did not necessarily preclude the possibility of other sites containing hazardous, toxic, or radioactive wastes from this inventory, as access to the Pecan Bayou and its tributaries was limited in many places.

Five Comprehensive Environmental Response Compensation and Liability Act Information System (CERCLIS) sites were identified from the database searches of hazardous, toxic, and radioactive activities in the study area. All five sites had a "no further action status", indicating cleanup or neutralization of the sites had taken place. Research of the Resource Conservation and Recovery Act Information System (RCRIS) database revealed no apparent HTRW releases in or near the study area.

There are two locations in the study area of concern. The first is at the USDA Pecan Field Station to the west of Pecan Bayou where a former municipal solid waste landfill had reportedly been operated within an old channel of Adams Creek. On March 20, 2000, the Fort Worth District conducted field investigations that concluded the waste to be municipal solid waste confined to the old channel alignment for Adams Creek.

The second site is a Formerly Used Defense Site (FUDS) at former Camp Bowie, just south of Willis Creek. This area's history of possible uncontrolled dumping in open pits, combined with its proximity to the creek, presents a possible environmental risk. On March 21, 2000, the Tulsa District, Corps of Engineers, which is responsible for FUDS work, initiated a site investigation, which included soil and groundwater sampling, surface water and sediment sampling from Willis Creek, and an electromagnetic survey to locate the limits of the landfill area. The results of the soil and groundwater showed only a few samples with elevated concentrations of specific contaminants. Based on the findings of the investigation this site may be closed under the Texas Natural Resource Commission (TNRCC) Risk Reduction Standard 3, which allows soils that pose no threat to human health and the environment to remain in place.

Socio-Economic Characteristics

The city of Brownwood, incorporated in 1948 is located in west central Brown County, about 120 miles west of downtown Fort Worth. The four-county area population (Brown, Mills, Callahan, and Coleman) in 1960 totaled 49,582, of which 23,345, or about 47 percent was urban. By 1990, the population of the four-county area had grown to 60,471, of which 37,308 (or 62 percent) lived in urbanized areas. The population in Brown County in 1990 was 34,371, with 18,387 in Brownwood alone. This shows a trend of increasing total population for the area at a rate of over 350 people per year and increasing urban population rate of over 450 people per year. As is common in most agricultural areas, changes in farm methods, increased mechanization, and improved transportation resulted in a decrease in rural population. The estimated population in 1998 was 19,534 for Brownwood and 36,889 for Brown County. The study area is a major manufacturing, trade, distribution, and finance center. Other significant contributors to the economy are agriculture, department of correction facilities, oil and gas operations, timber, and tourism. The principal manufacturing activities of the area consist of the manufacture of clothing, plumbing fixtures, brick and tile, farm machinery, leather goods, feed and cottonseed oil products, and the processing of foods, dairy products, meat and poultry. Manufacturing activities in Brownwood employ approximately 4,000 workers. Agriculture is of major importance and contributes substantially to the economy of the area. The principal farm crops grown are wheat, peanuts, and hay. There is also a large production of pecans along the streams. Livestock raised in the area include beef cattle, sheep, goats, and swine. Production of wool and mohair is of major importance. The 1999 county unemployment rate was 3.6 percent, compared to the state unemployment rate of 4.3 percent. This low unemployment rate is reflected in the areas personal income. Personal income is considered the most comprehensive measure of economic activity available in this study since it maintains a close and generally constant relationship with the gross national product. The average per capita income for the county in 1998 was approximately $18,800 compared with the state average of approximately $25,400. The estimated population in 2000 exceeded 19,800 in Brownwood and 37,000 in Brown County.

Recreational Resources

The *1990 Texas Outdoor Recreation Plan* (TORP) remains the most comprehensive source of information available for determining recreational needs in the state of Texas. The City of Brownwood and Brown County are within the 19-county West Central Texas-Planning Region 7.

Region 7 has over fifty-seven thousand surface acres of lakes. Because of the even distribution of these lakes and their associated parks, most cities have good access to recreational facilities. Significant streams in the region include the various forks of the Brazos River, Pecan Bayou, and the Colorado, Leon, and Wichita rivers. The U.S. Army Corps of Engineers facilities at Hords Creek Lake and Proctor Lake are very popular with Region 7 residents and visitors. Three state parks and a historical park are major attractions that draw recreationists from all over the state, particularly the West Texas and Dallas-Fort Worth areas.

There are nearly twenty-one thousand acres of recreation land in Region 7 distributed among 217 parks. With about fifty-eight acres of recreation land per thousand population, the region ranks well below the statewide average of 209 acres per thousand. Local governments supply the largest proportion of the total recreation land with 37 percent. The next largest supplier is the Corps of Engineers, at 31 percent, followed by the commercial sector, 21 percent, and the Texas Parks and Wildlife Department, 10 percent. Local governments also furnish the largest number of parks at 133.

In 1995 the most popular activities in Region 7, in terms of percentage of the population participating, were projected to be walking for pleasure, picnicking, pool swimming, playground use, freshwater fishing, and freshwater swimming, respectively. Region 7 residents are active outdoors and enjoy a variety of recreational activities. Activities projected to exceed the statewide rate in user occasions per capita in 1995 are freshwater boating, camping, all types of freshwater fishing, hunting, lake use, picnicking, freshwater swimming, baseball and off-road vehicle use.

The existing Lake Brownwood is also valuable for recreational activities. Commercial, private, and state park recreational facilities located along Lake Brownwood shoreline area, excluding lands, has a present estimated value of over $30,000,000. Much of the area around lake Brownwood has been developed for cabin, cottage, lodge encampment, commercial recreational businesses, and permanent homes. The area provides many cabins and camping areas, swimming areas, docks, and boathouses. The shoreline area is undergoing extensive subdivision and the amount of recreational improvements is expected to increase considerably in the future. The Lake Brownwood shoreline area includes the Lake Brownwood State Park area. The State Park area involves an area of about 500 acres and includes cabin areas, playground areas, and facilities for boating, fishing, swimming, picnicking, and dancing. Lake Brownwood has a normal water surface area of about 7,500 acres and a shoreline distance of about 95 miles.

Future population growth in Region 7 should not greatly impact recreation resources. Lakes, parks, and cities are fairly well distributed throughout the region, and, except for Abilene, there are no large population centers that would create undue impacts.

Water Supply

Major suppliers in the upper basin are the Lower Colorado River Authority, Colorado River Municipal Water District, and irrigation companies in the lower basin. Ground water supplies are obtained from six major and several minor aquifers through the basin. The Ogallala, along with the Edwards-Trinity and Dockum aquifers, occur in the upper part of the basin. The Edwards-Trinity and Lipan aquifers are in the west-central part. The Trinity, Edwards-Balcones and Carrizo-Wilcox are in the south-central basin along with several minor aquifers. The Gulf Coast aquifer occurs in the lower basin.

In response to Senate Bill 1, passed by the 75th Texas Legislature in 1997, the Texas Water Development Board created 16 regions across the state to plan for the water needs of the state for the next 50 years. The area in and around Pecan Bayou is situated within Region F which consists of 32 counties in west Texas. Six major rivers and 17 water supply reservoirs characterize the region’s surface water hydrology. Additionally, 11 aquifers lie within the region, six of which provide significant water to the region. There are three providers of regional wholesale water in Region F; the Colorado River Municipal Water District, Brown County Water Improvement District Number One, and the Upper Colorado River Authority.

As of 1998, Region F had an estimated population for 2000 of 638,000 or 3 percent of Texas's population. Nearly half of the regions population is situated in three metropolitan areas (Midland, Odessa and San Angelo). The cities of Brownwood and Big Spring have populations greater than 20,000. The region's population is expected to increase to 922,000 over the next 50-year planning horizon.

The total water demand for the region is expected to increase from 881,500 acre-feet per year in 2000 to 900,200 acre-feet per year in 2050. The main water users presently are: irrigated agriculture (73.6%), municipal (16.7%), mining (3.5%), livestock (2.8%), power (2.4%), and manufacturing (1.0%). Only municipal, manufacturing, and power water demands are projected to increase by 2050 while the remainder is projected to remain the same or decrease.

The current supply of water for Region F consists of reservoirs, ground water, local supplies, and wastewater reuse. Ground water is by far the largest source (66%) and reservoirs contribute 21% of the supply. The latter have an estimated supply of 243,600 acre-feet per year in 2000 and are expected to decrease due to sedimentation to 235,100 acre-feet per year in 2050.

PROBLEM IDENTIFICATION

As previously discussed, the primary study area is defined as the 500 year Standard Project Flood Plain along Pecan Bayou from U.S. Highway 377, extending downstream to the confluence of Willis Creek, a distance of approximately 7,500 feet. On Willis Creek, the study area begins at its confluence with Pecan Bayou and extends upstream a distance of about 22,000-feet, terminating near Asbury Street.

HISTORY OF FLOODING

The city of Brownwood has experienced frequent flooding along Pecan Bayou and Willis Creek ever since the first settlers arrived at it banks in the early 1800's. Flooding has been documented as early as 1868. Recorded "great" floods occurred in 1868, 1875, 1900, 1908, and 1915. One "great" flood occurred in September 1900, which was prior to the construction of Lake Brownwood.

This flood had a stage of 21.7 feet and an estimated peak discharge of 150,000 cubic feet per second. Discharges high enough to cause significant damages tend to occur in clusters of consecutive or non-consecutive years. The years following the wet cycle are usually characterized by smaller, non-damaging flows. Flood events have been modified by the construction of Lake Brownwood (1932) and Hords Creek Reservoir (1948). However, these projects have only partially eliminated flooding problems along Pecan Bayou and its tributaries.

Since urbanization is a major contributing factor to the current and future flooding problems, it is important to examine floods that have occurred in more recent years. Significant floods have occurred along Pecan Bayou in 1980, 1982, 1984, 1986, 1990, 1991, and 2000.

Heavy rains (five inches) over a five-day period culminated on December 31, 1984, when three inches of rainfall produced excessive runoff from the already saturated ground. Numerous roads, houses, apartments, and school buildings were inundated to various depths. Property losses were reported to have exceeded $500,000. Rainfall from this flood occurred below the control of Lake Brownwood, as the spillway was not overtopped in this event.

On June 5, 1986 up to six inches of rain caused Pecan Bayou to overflow its banks. The high water from Pecan Bayou forced the closure of several major and minor streets in the central business district of the city. Some minor structure flooding was reported but no estimates on these losses are available.

In 1990, major portions of central Texas experienced heavy rainfall over a 3-week period as a result of a cold front mixed with an upper level low and produced two frontal type storms. Between April 17 and May 4, rainfall amounts up 18 inches were recorded in the Brownwood area. The rain led to record water levels at Lake Brownwood. Water surged more than 7 feet over the lake's emergency spillway. By mid-morning of April 26, most routes from the city were severed and a normally bustling traffic circle was submerged under several feet of water. Brownwood remained underwater for 5 days with 7 feet of water covering most of the commercial area along highway 377. In the city of Brownwood, 528 homes and 70 businesses were either damaged or destroyed. Public and agricultural facilities were also damaged. In addition to the economic damages from this

flood, two residents of the city were swept away by the flood and drowned. Flood damages and associated costs were estimated to exceed $10 million (1990 cost estimate). On May 2, 1990, the President declared the State of Texas a major disaster area due to the severe flooding.

In December 1991, Brownwood, as well as large portions of southeastern Texas (Austin, San Antonio), experienced record rainfalls. The Brownwood area received between 8 and 12 inches of rain. Brown County and the city of Brownwood reported a total of 213 local dwellings affected by flood waters, with 26 totally destroyed and another 125 sustaining major damage; 10 residences sustained approximate damages of $100,000. Businesses sustained over $580,000 in damages in this flood event, not including lost revenue. The damage to residential structures around Lake Brownwood included 92 homes severely damaged, 26 homes with minor damage, 26 mobile homes destroyed, 32 mobile homes with major damage, and 14 mobile homes with minor damage. Brown County was declared a disaster area in December 1991.

In the early morning hours of June 15, 2000, an isolated storm dumped over 8 inches of rain on the city of Brownwood causing street and residential flooding, and necessitating the evacuation of 125 city residents, including some by helicopter. Official reports indicated that all of the creeks and streams in Brownwood had overflowed their banks. Along U.S. Highway 377 at the east of the city, public streets and commercial parking lots were flooded and roads were closed to traffic. At the peak of the storm, the city's emergency sirens were activated to warn residents of the flooding conditions. Consideration was given to requesting assistance from the National Guard, but the storm abated before such a call was initiated. Flood damage and costs estimates are not available on this storm.

Pecan Bayou Flood Pattern

Under normal flows, waters remain within the channel and “trickles” over the dam. During a flood event, water initially spills out of Pecan Bayou immediately upstream of the Riverside Park dam. During storm events, the dam, by impeding flow, is a contributory factor to water leaving the channel. From Lake Brownwood, water traverses in a southerly direction, crossing U.S. Highway 377, inundating the northeastern portion of town. At this point, a portion of the overland flow is captured by the Pecan Bayou slough. Pecan Bayou slough is the remnant of the historical Pecan Bayou channel that has over geological time, meandered to its existing location. The Pecan Bayou slough originates slightly upstream of U.S. Highway 377. It flows generally southeast, somewhat parallel to Pecan Bayou until it joins Pecan Bayou approximately 2 miles downstream. The slough is fairly shallow and has many meanders as it flows along the eastern edge of the city. The existing bottom width of the slough is approximately 10 to 15 feet and it is highly vegetated along its banks. The existing hydraulic capacity is limited.

Entering the Pecan Bayou slough downstream of U.S Highway 377 is Adams Branch. This small tributary originates west of Brownwood, and flows in an easterly direction through the northern portion of the city. Hydraulically speaking, storm events within the Pecan Bayou watershed are the controlling factor on the lower reaches of Adams Branch. However, localized precipitation within the Adams Branch watershed may cause flooding without any inundation from Pecan Bayou. Regardless, given the existence of a NRCS stream bank erosion structure on Adams Branch, and in accordance with the desire if Brownwood, this feasibility study does not address flooding specific solely to Adams Branch.

EXISTING FLOOD DAMAGES

The Hydrologic Engineering Center-Flood Damage Assessment Program (HEC-FDA) was utilized to facilitate the evaluation of flood damages. The program integrates hydrologic, hydraulic, and economic analyses through application of the Monte Carlo simulation. This program computes the expected annual damage value while accounting for uncertainty in the basic value. Expected annual damage (EAD) is the mean damage obtained by integrating the damage exceedance probability curve for the damage reach. The damage exceedance probability curve results from the discharge-exceedance probability, stage-discharge and stage-damage functions derived at each reach index location.

Estimates of flood damages are determined as a single, annualized expected value, and on a probabilistic basis. The classical nomenclature describing the relative risk of flooding has been revised to reflect the actual probability, rather than the average recurrence interval, of flood events. For example, the commonly used term "100-year frequency flood", meaning that flood which stands a one percent chance of being equaled or exceeded in any given year period will hereafter be described as the "1 percent annual chance exceedance (ACE) flood." For convenience, the new probabilistic nomenclature will be abbreviated as "1 percent ACE flood."

Using the appropriate water surface profiles, the depth of water at each structure within the study area is calculated for the 100, 50, 20, 10, 4, 2, 1, 0.4, 0.2, and 0.1 percent ACE flood events (or the 1-, 2-, 5-, 10-, 25-, 50- 100-, 250-, 500-, and 1000 year flood, respectively.) These depths were combined with the damage susceptibility factors and estimated values to estimate expected annual damages.

Damage susceptibility factors used to estimate flood damages include the number and type of structures within the flood plain, the value of the property, the elevation at which the structure begins to sustain measurable damages, and a flood depth-damage relationship. Existing damageable properties were classified into major damage categories as follows: residential (single and multifamily dwellings and associated private vehicles), commercial, and railroad facilities. A floodplain inventory was completed within the study area. This inventory included enumeration of the numbers and types of structures. Further, the appraised value of each structure was obtained from the Brown County Tax Appraisal District. Determining replacement cost less depreciation is basically the same as the Cost Approach (outlined in the Corps of Engineers guidelines) for deriving values from an appraisal standpoint. This information has been continually updated as the study has progressed and remains current for the purposes of this report.

Pecan Bayou

A total of 737 damageable structures were identified within the 0.2 percent ACE limits Pecan Bayou and Adam Slough study limits as indicated in Table 1. Approximately 70% of the total investment values identified are commercial, while 11% are residential. The total floodplain investment within the .2 percent ACE limits is valued at about $ 81.5 million based on May 2000 prices and level of development. The average structure value of single-family residences is about $14,000 and constitutes only 11 percent of the total flood plain investment, while the average value of commercial structures (structure and contents) average $130,000 and accounts for approximately 70 percent of the total flood plain investment.

The remaining percentage represents losses in multifamily units, privately owned vehicles, and railroad tracks. Table 2 shows the cumulative estimated single occurrence flood losses under existing conditions for Pecan Bayou.

Table 1

Estimated Investment Value of Pecan Bayou and Adams Slough

Flood Plain Properties

($1000's, based on May 2000 prices and levels of development)

Type	Number	Structure	Content	Total
Commercial	274	$35,000	$22,000	$57,100
Single Family	450	$6,200	$3,000	$9,100
Multi-Family	13	$300	$100	$400
Subtotal	737	$41,500	$25,100	$66,000
Vehicles				$1,100
Rail				$13,000
Total Investment	**737**	**$41,500**	**$25,600**	**$81,500**

Table 2

Pecan Bayou Cumulative Estimated Single Occurrence Flood Losses

Structures, Contents under Existing Conditions

($1000's, based on May 2000 price and development level)

Flood Event	Commercial		Single-Family*		Multi-Family		POV	Rail	Total
	Damage	No.	Damage	No.	Damage	No.	Damage	Damage	Damage
20%									
10%	$ 710	38	$ 60	17	$ 20	1	$ 20	$ 30	$ 840
4%	$ 4,710	99	$ 550	61	$110	9	$ 140	$ 180	$ 5,690
2%	$ 7,850	129	$1,130	126	$180	9	$ 250	$ 480	$ 9,890
1%	$11,200	141	$1,960	222	$240	9	$ 410	$1,020	$14,830
0.4%	$19,020	204	$4,400	366	$350	13	$ 810	$2,950	$27,530
0.2%	$24,070	274	$6,540	450	$390	13	$1,130	$4,770	$36,900

*Includes mobile homes.

Willis Creek

A total of 322 damageable structures were field identified within the .2 percent ACE limits of Willis Creek with the majority of the structures identified are single family residential as shown in Table 3. The total estimated value of the flood plain investment is about $37.3 million, based on May 2000 prices and level of development. Residential values constitute 88 percent of the total flood plain investment with an average value of $65,500 for single-family residences and their contents. The remaining investment of $2.5 million stems from privately owned vehicles. Table 4 presents a summary of the cumulative number and type and the associated damages of affected structures and vehicles, by flood occurrence not accounting for risk and uncertainty.

Table 3

Estimated Investment Value of Willis Creek

Flood Plain Properties

($1000's, May 2000 prices and levels of development)

Type	Number	Structure	Content	Total
Commercial	5	$ 400	$ 300	$ 700
Single Family	296	$ 19,400	$ 9,700	$ 29,100
Multi-Family	21	$ 3,300	$ 1,700	$ 5,000
Subtotal	322	$ 23,100	$ 272	$ 34,800
Vehicles		$ 2,500		$ 2,500
Total Investment		$ 25,600	$ 272	$ 37,300

Table 4

Willis Creek Cumulative Estimated Single Occurrence Flood Losses
Structures, Contents under Existing Conditions

($1000's, based on May 2000 price and development level)

Flood	Commercial		Single-Family*		Multi-Family		All Structures		POV	Total
Event	Damage	No.	Damage	No.	Damage	No.	Damages	No.	Damage	Damage
20%			$ 606	52	$ 266	4	$ 872	56	$ 23	$895
10%			$2,889	138	$ 521	6	$3,410	144	$ 155	$3,565
4%			$5,006	205	$ 746	9	$5,751	214	$ 438	$6,189
2%		1	$6,385	242	$ 924	13	$7,309	255	$ 696	$8,006
1%	$ .5	3	$7,280	260	$1,065	13	$8,347	276	$ 882	$9,229
0.2%	$30.4	5	$8,350	296	$1,225	21	$9,591	322	$1,305	$11,939

A predominance of residential structures is found within the 10% ACE flood plain and constitutes 95 percent of the expected annual damages. Based on May 2000 prices, expected annual flood losses to structures in the study area total an estimated $956,700 in damage. It is estimated that an .2 percent ACE event could cause structure and content damages of about $11.8 million. This would represent a loss of about 45 percent of the .2 percent ACE floodplain investment. The one-percent ACE could produce flood approaches the damages of $9.2 million, while the 10 percent event produces about $3.6 million in damages. A predominance of residential structures would be subject to flooding in all the flood zones. Overall, about 85 percent of the damageable property identified would be subject to the one-percent ACE flood event. Properties within the 10 percent ACE flood event constitute about 45 percent of the total number of structures potentially damaged along Willis Creek. Table 5 displays the existing expected average annual damages in the Willis Creek study area.

Table 5

Existing Expected Average Annual Damages

($1000's, based on May 2000 prices and level of development)

Property Type	Annual Damages
Single-Family	$ 755.2
Multi-Family	$ 131.2
Commercial	$ 1.4
Vehicles	$ 68.9
Total	**$ 956.7**

RECREATIONAL OPPORTUNITIES

The need for recreational outputs within the watershed is limited, particularly in the City of Brownwood. Those recreational facilities typically associated with local flood damage reduction projects such as parks, playgrounds, hike and bike trails are in sufficient supply in Brownwood and the immediate vicinity. Given that the City did not desire such features to be included in any recommended plan, further studies regarding recreation opportunities were not pursued.

ECOSYSTEM RESTORATION OPPORTUNITIES

This feasibility study does not include any detail investigations of ecosystem restoration opportunities. The local sponsor did not desire such features to be included in any recommended plan. Therefore, further studies regarding ecosystem restoration were not pursued.

WATER SUPPLY OPPORTUNITIES

On a regional basis, the total water demands in Region F exceed the currently available supplies throughout the 50-year planning period. Shortages increase from 170,000 acre-feet per year in 2000 to 200,000 acre-feet per year in 2050. Most of these shortages result from large irrigation demands that cannot be met by ground water during drought conditions. Flood control reservoirs were eliminated from consideration during the reconnaissance phase. No measures were pursued during the feasibility phase to address the water supply needs of the Region. Therefore, further studies regarding water supply were not pursued.

PLAN FORMULATION

Plan formulation is the process of developing and evaluating alternatives that meet planning objectives and avoid planning constraints. This chapter details this process of stating the planning objectives and constraints, the initial screening of measures, the evaluation of alternatives, and the selection of the recommended plan.

PLANNING OBJECTIVES

Planning objectives are an expression of public and professional concerns about the use of water and related land resources resulting from the analysis of existing and future conditions in the study area. The planning objectives for the period of analysis between the years 2005 to 2050 are as follows.

1. Reduce flood damages to structures and their contents as well as vehicles, along Pecan Bayou and Willis Creek within the city of Brownwood.

2. Reduce the potential for loss of life associated with inundation, high velocities, isolation, and/or overtopping of roads and bridges, along Pecan Bayou and Willis Creek within the city of Brownwood.

3. Reduce flood damages to public facilities such as roads, bridges, utilities, schools, churches, etc., along Pecan Bayou and Willis Creek within the city of Brownwood.

4. Reduce the public and private costs associated with flood fighting and recovery along Pecan Bayou and Willis Creek within the city of Brownwood.

5. Reduce the disruption and costs associated with the closure of highways and streets along Pecan Bayou and Willis Creek within the city of Brownwood.

6. Reduce business and commercial losses resulting from a loss of production and/or economic activity for establishments along Pecan Bayou and Willis Creek within the city of Brownwood.

7. Improve the overall health, safety and quality of life of the citizens of city of Brownwood, the state of Texas, and the United States of America.

8. Establish a National Economic Development Plan (NED).

PLANNING CONSTRAINTS

In development of flood damage reduction alternatives, the following constraints or limitations were identified to direct plan formulation efforts such that beneficial impacts would be maximized and adverse effects would be minimized:

1. Alternatives will be limited to the study area within the city of Brownwood along Pecan Bayou and Willis Creek.

2. The city of Brownwood will not support any alternative on Pecan Bayou which involves the removal of Riverside Park dam.

3. The formulation of alternatives that reduce flood damages and costs in one area should not result in the measurable increase in the extent and magnitude of flooding in another area.

4. The formulation of alternatives must avoid adverse effects to significant ecological and environmental resources; and if avoidance is not feasible, then adverse effects to ecological and environmental resources must be minimized. Unavoidable adverse effects to these resources must be mitigated.

5. The formulation of alternatives must avoid adverse effects to significant cultural resources; and if avoidance is not feasible, then adverse effects to cultural resources must be minimized. Unavoidable adverse effects to cultural resources must be mitigated.

6. The formulation of alternatives should avoid areas that are either known or suspected to be contaminated and/or contain hazardous, toxic, and radioactive waste.

7. The formulation of alternatives must avoid adverse effects to occupied land.

8. The formulation of alternative must avoid adverse aesthetic and visual effects.

9. Total annual benefits must equal or exceed total annual costs for a plan to be implemented.

10. The recommended plan must be generally acceptable to the public.

11. The recommended plan must have a local non-Federal sponsor.

PLAN FORMULATION RATIONALE

Plans are formulated to meet planning objectives and to adhere to the constraints. The following paragraphs discuss the technical, economic, environmental, and social criteria used to develop the formulated alternatives to meet the stated study objectives.

Technical Criteria

In order to develop a plan that would satisfy the primary objective of reducing flood damages and costs within the study area, the following technical criteria were adopted for use in developing, evaluating, and comparing alternative plans:

1. The plan should be effective and efficient with regard to alleviating the specified problems and achieving the specified goals.

2. The plan must be technically feasible using engineering methods and equipment available in the study region.

3. Plans should be adequate to provide a project life of at least 50 years.

4. Existing facilities should be utilized to the maximum extent possible.

5. The plan is to be complete within itself and not require additional future improvements other than normal replacements, and operation and maintenance.

6. The plan is to be designed using engineering criteria taken from appropriate Corps of Engineers engineering and design manuals and regulations related to flood damage reduction alternatives.

Environmental and Social Criteria

Plans formulated under Federal directives should be consistent with protecting the existing environment by the management, conservation, preservation, creation, restoration, or improvement of the quality of certain natural and cultural resources and ecological systems in the proposed project area. Structural and nonstructural measures must be evaluated in accordance with guidelines established by the National Environmental Policy Act of 1969 (Public Law 91-190), as amended, and the P*rinciples and Guidelines for Water and Related Land Resources Implementation Studies*, as developed by the U.S. Water Resources Council, dated July 1983. The following environmental and social criteria were considered:

1. Protect against possible loss of life, property, and hazards to the health and safety of area residents, and preserve, maintain, or enhance community cohesion and desirable community and regional growth.

2. Preserve and/or enhance social, cultural, educational, and aesthetic values as well as historical and cultural attributes of any sites within the project area.

3. Promote the development of areas of natural beauty and human enjoyment and protect areas of valuable natural resources.

Economic Criteria

The National Economic Development (NED) objective is the maximization of the economic worth of alternative plans as set forth in *Principles And Guidelines For Water And Related Land Resources Implementation Studies*. The NED objective is to increase the nation's output of goods and services and improve economic efficiency. For flood damage reduction projects, this objective relates to a plan's capability to prevent flood damages and costs (economic benefits). The amount that a project's economic benefits exceed the project cost (when both are expressed in annual terms) is defined as the net benefits of the plan. In the plan formulation process, the plan that meets the planning objectives and falls within the planning constraints, yields the greatest net benefits, and best meets the objective of NED.

Economic feasibility of a plan is measured as a relationship of benefits-to-costs. Benefits are the monetary savings due to damages prevented, reduction in the cost of emergency services, and the reduced disruption of the local economy. These benefits are subsequently annualized to represent a yearly benefit applicable for the life of the project. The project cost, are also annualized so as to represent an annual project cost, applicable for the analysis period of the project. The annual benefits and the annual costs are then related in a benefits-costs ratio (BCR). To be economically feasible, a plan must have benefits which equal or exceed costs, i.e., a BCR equal to or greater than 1.0.

To meet the Federal guidelines for planning water resource projects, the following economic criteria were followed:

1. All plans must be economically feasible, which dictates that the plan's flood reduction benefits must exceed the cost of the plan. Measures for mitigation, restoration, and protection of environmental resources must be justified based on a combination of tangible and intangible benefits.

2. The alternative being selected as the recommended plan should reasonably maximize benefits over costs consistent with protecting the Nation's environment, while meeting the planning objectives and avoiding the planning constraints. Each separable unit or purpose of a given alternative must provide benefits at least equal to its costs.

3. Alternatives will be evaluated using the current price level, a 50-year period of analysis, and the current Federal discount rate for water resource projects as determined by the U.S. Department of Treasury.

4. Annualized costs include the cost of operation, maintenance, repair, replacement, and rehabilitation (OMRR&R).

SCREENING OF ALTERNATIVES

Various alternatives were identified and evaluated in an effort to achieve the stated planning objectives and to adhere to the constraints. The alternatives can be categorized as the "no action" alternative, nonstructural alternatives and structural alternatives. The initial screening of alternatives eliminated those alternatives that obviously failed to meet the minimal technical, economic and/or environmental criteria, and evaluated in terms of completeness, effectiveness, efficiency, and acceptability. Completeness is the extent to which an alternative provides and accounts for all necessary investments or other actions to ensure the realization of the planned effects. Effectiveness is the extent to which an alternative alleviates the specified problems and achieves the specified objectives. Efficiency is the extent to which an alternative is the most cost-effective means of alleviating the specified problems and realizing the specified opportunities, consistent with protecting the Nation's environment. Acceptability is the workability and viability of the alternative with respect to acceptance by the State and local entities, and the public and compatibility with existing laws, regulations, and public policies. Those alternatives remaining after the initial screening receive additional detailed investigations.

No Action

The "no action" alternative would not recommend that any type of project, nonstructural or structural, be implemented. While the no action alternative would not require the expenditure of Federal funds, adoption of this alternative implies acceptance of the existing and future flood damages and other adverse impacts caused by continued flooding. Although flood insurance would partially compensate for flood damages, they would still be incurred. The financial burden of nearly $ 1.0 million in annual flood damages for flood fighting and recovery costs, public damages, the potential loss of life, and the overall threat to health and safety would continue under the no action alternative. The no- action alternative does not meet the previously stated planning objectives. This alternative would be unacceptable to the city of Brownwood if a feasible alternative were identified.

Nonstructural Alternatives

Nonstructural measures attempt to avoid flood damages by exclusion or removal of damageable properties from flood prone areas. These measures do not affect the frequency or level of flooding within the floodplain; rather they affect floodplain activities. Nonstructural alternatives include the following; regulation of the flood plain use, flood forecasting and warning (temporary evacuation) flood-proofing, elevating structures, relocating structures, permanent evacuation.

Regulation of Floodplain Uses

Floodplain management is most effective in controlling future development of the floodplain, thereby assuring that the existing flood problems do not become worse. However, floodplain management cannot, by itself, significantly alleviate existing flooding conditions within an existing floodplain. The technique of controlled land use is particularly helpful in planning for future development but is of limited use in present developed areas. Effective regulation of the floodplain is dependent on developing enforceable ordinances to insure that floodplain uses are compatible with the flood hazard. Several means of regulation are available, including zoning ordinances, subdivision regulations, and building codes. Zoning regulations permit prudent use and development of the floodplain in order to prevent excessive property damage, expenditure of public funds, inconvenience, and most important of all, loss of life, due to flooding. Subdivision regulations guide the division of large parcels of land into smaller lots, and typically require the developer to show compliance with subdivision regulations, zoning ordinances, the local land use or master plan, and other regulations. A subdivision ordinance would require installation of adequate drainage facilities, prohibit encroachment into floodway areas, require the placement of critical streets and utilities above a selected flood elevation, and building lots or structures above a selected flood elevation, normally one foot above the 100-year floodplain elevation. Building codes specify the building design, materials and construction methods used for both construction of new buildings or repair of flood-damaged structures.

The city of Brownwood currently holds about $4.4 and $20.1 million of Federal Emergency Management Agency's, National Flood Insurance Program (NFIP) and Write-Your-Own flood insurance protection, respectively. The City has been enrolled in NFIP's Regular Program since June 20, 1975. Since the inclusion into this program, Brownwood has enacted and enforced numerous floodplain land-use restrictions, regulation, zoning ordinances, subdivision regulations, and building codes. While these measures will not reduce flood damages the majority of the existing structures in the study area, they are important management tools. Regardless, this does not warrant further evaluation. It should be noted that the city of Brownwood will be required to complete and implement a flood plain management plan within one-year of the completion of any flood damage reduction plan recommended and implemented by the Corps of Engineers.

Flood Forecast and Warning

Flood forecast and warning involves the determination of imminent flooding, implementation of a plan to warn the public, and organization of assistance in evacuation of persons and some personal property. Notification of impending flooding can be by radio, siren, individual notification, or by more elaborate means such as remote sensors to detect water rise levels and automatically warn residents. These measures normally serve to reduce the hazards to life and damage to portable personal property. Flood warning and emergency evacuation should be considered as part of any flood control plan. This alternative also includes the use of flood forecasting to revise the current flood control-operating plan of area lakes to provide additional flood control protection.

The city of Brownwood has a highly effective and efficient workforce that mobilizes during storm events to visually monitor rainfall and river stages. Additional information from Lake Brownwood provides ample time for the mobilization of resources to address Pecan Bayou. Flood forecasts and warnings are not considered further in this study.

Flood-proofing

Flood-proofing structures involves providing watertight coverings for door and window openings, sump pumps to drain seepage, sealing of cracks, steel bulkheads on brick walls (flood shields) to close off entrances, coating walls of structures with a waterproof membrane. Flood proofing is generally applicable where flooding is of short duration, low velocity, infrequent, of shallow depths, and requires significant modifications to structures. For water levels that are lower than the first floor of a home, flood proofing would certainly be a possibility. However, if a sustained water level in excess of one foot of the first floor elevation, the structural stability of a watertight home becomes a critical factor. A flood-proofed structure generally cannot withstand

hydrostatic pressures when floodwaters rise three feet above the lowest floor. In addition, flood proofing introduces uncertainties in the degree of protection, since the owner must be present (or awake) to close off windows, doorways, etc. Additional shortcomings include not protecting public facilities such are roads, bridges and utilities, and the continued threat of road closures and the isolation of residents trapped in there homes and businesses. While flood proofing would not likely result in any significant or permanent adverse impacts to ecological or cultural resources, and is appropriate under certain conditions, it does not address the planning objectives or criteria previously discussed. Therefore, flood proofing will not be considered further for either the Pecan Bayou or Willis Creek study areas.

Elevating Structures

This alternative avoids flood damages by elevating damageable property. Elevating is most practical for structures that have access below the first floor (i.e. piers and columns), are light enough to be jacked, and are relatively small. Wood frame structures are particularly suited for rising. Rising structures with slab foundations or basements is not generally economically feasible. The design of the foundation walls or piers must withstand forces from flowing water to ensure lateral stability of the structure. Furthermore, elevating structures has similar limitations as flood proofing, namely protecting public facilities, the continued threat of road closures, and the isolation of residents trapped in their homes and businesses. While elevating structures would not likely result in any significant or permanent adverse impacts to ecological or cultural resources, and is appropriate under certain conditions, it does not address the planning objectives or criteria previously discussed. Therefore elevating structures will not be considered further for either the Pecan Bayou or Willis Creek study areas.

Permanent Evacuation

This alternative (also known as the “buy-out”) involves the acquisition, demolition, the removal of structures from the flood plain, and the relocation of residents to flood-free housing. The practicality of evacuation depends on several factors. They include the frequency and severity of flooding, the willingness of residents to move out of the flood plain, the availability of flood-free housing, the value of the property, and the need for areas of a more compatible floodplain use such as parks or nature areas. Permanent evacuation can be a very effective means of reducing flood damages, as well as public damages and costs.

Past investigations have demonstrated that permanent evacuation is typically cost effective only up to and including the 10% ACE flood plain. Within the Pecan Bayou study area, there are a total of 46 structures (34 commercial, 12 residential) within the 10% ACE flood plain. Within the Willis Creek study area; flood damages to structures and their contents begin at about the 20% ACE flood event. There are a total of 56 structures within the 20% ACE flood plain (52 single family residential and 4 multifamily residential), and 144 structures within the 10% ACE flood plain (138 single family residential and 6 multi-family residential). Given that the majority of structures within the Pecan Bayou study are commercial, the difficulty and high costs of relocating commercial establishments, and Brownwood’s reluctance to risk the loss of revenue, permanent evacuation will not be considered further on Pecan Bayou. However, further investigation of permanent evacuation would be required on Willis Creek.

Structural Alternatives

Structural alternatives are designed to control, divert, or exclude the flow of water from flood prone areas to the extent necessary to reduce damages to property, hazard to life or public health, and general economic losses. The structural measures considered most appropriate in dealing with the character of the flood problems encountered in the study area are modification to Lake Brownwood, detention, levees and floodwalls, hydraulic channel improvements including bridge modifications, and diversion.

Detention

This alternative consists of constructing one or more structures to provide flood control storage to detain peak flood flows and lessen downstream flood damages. Detention is used to

temporarily impound floodwaters for later release when the downstream conditions permit. The feasibility of this measure depends heavily on the volume and timing of the flood flows, and the availability of an impoundment site capable of providing sufficient storage. Additional costs would also be incurred to mitigate for adverse environmental impacts.

Detention structures of various sizes and capacities, located at two sites above Lake Brownwood, were previously investigated for Pecan Bayou during the reconnaissance study. Out of the ten different detention configurations investigated, none had a benefit-cost ratio greater than 0.2, well below that required for economic feasibility. Conditions in the city of Brownwood are similar to what they were at that time, therefore no additional efforts were viewed as warranted for a detention reservoir in this feasibility study, and this alternative was screened from further consideration.

In the upstream reaches of Willis Creek, there are several detention structures that were constructed by the NRCS. These structures retain a substantial percentage of the rainfall in the upper Willis Creek watershed. For this study, a brief hydraulic analysis of a new detention reservoir near Crockett Street was conducted. Investigations revealed insufficient space available, and this alternative was not considered further.

Levees and Floodwalls

Levee systems traditionally provide high levels of protection to flood prone areas but often require substantial amounts of real estate between the stream and the structures being protected unless an existing levee is in-place and only a small strip of real estate is required. Floodwalls (usually made of concrete) are used in lieu of levees in situations where the acquisition of real estate for the levee or other topographic problems may be prohibitive. The feasibility of either of these measures is based on the cost and availability of real estate, the number of structures along the levee alignment, and the additional costs necessary to alleviate interior drainage problems to prevent induced damages in adjacent areas. Construction of individual levees or floodwalls around specific structures or small groups of structures is normally considered cost prohibitive unless the individual structure is very valuable and/or has cultural significance and is prone to frequent flooding.

A levee system alternative was considered along both Pecan Bayou and Willis Creek. However, the close proximity of structures to the waterways and the lack of available space, made a levee physically infeasible because of the anticipated high relocation cost associated with removal of the structures where the levees would be constructed. Floodwalls, which require less real estate acquisition, are historically much more expensive than any other alternative, either structural or nonstructural. Based on the minimal benefit-cost ratios estimated for other flood protection alternatives, and because of the large number of structures and length of the floodplain, the floodwall alternative would be prohibitively expensive. The non-Federal sponsor and residents of the area expressed that this was the least desirable solution to the flooding problems, due to the adverse aesthetics of this alternative. Therefore, levees and floodwalls were eliminated from further consideration.

Hydraulic Channel Improvements and/or Bridge Modifications

This measure consists of modifying an existing channel by either increasing the cross-sectional area of the stream channel and/or an existing bridge (widening and/or deepening), straightening and realigning the stream channel, and/or reducing the friction losses of an existing channel through concrete lining. The design of the channel modification can vary significantly and is primarily based on the topography of the existing stream channel and the existing development of properties within the floodplain. The study area of Pecan Bayou and Willis Creek meets the minimum flows, minimum drainage area, and urban drainage criteria required under current policies. Other factors to consider in the design of these hydraulic channel improvement alternatives include the existence of known or potential significant ecological and cultural resources as well as contaminated material.

The hydraulic channel improvement alternative investigated in the 1994 reconnaissance study on Pecan Bayou was a grass-lined channel beginning at U.S. Highway 377 and extending

downstream a distance of 7,500 feet. Based on a Reconnaissance level of investigation, the channel would have a bottom width of 50-feet with side slopes of 1 vertical on 3 horizontal (1V:3H). The modified channel slope would average about 0.02 percent. Excavation of both the channel side slopes and bottom would be required. The banks would be steeper at the Woodson Road Bridge to enable the improved channel to have a smooth transition in and out of the bridge; further, the existing bridge concrete columns would be encased to compensate for the channel excavation under the bridge. There is also some minor utility relocation required. The project first cost was estimated at $2,845,000 (January 1994 price level). Annual costs and expected annual benefit were estimated at $257,000 and $320,300, respectively. The benefit-cost ratio was 1.2 to 1.0. Accordingly, a hydraulic channel improvement on Pecan Bayou warranted further investigation.

The hydraulic channel improvement investigated in the 1994 reconnaissance study on Willis Creek was a grass-lined channel. The first segment of the improved channel begins near Asbury Street and extends approximately 1,670-feet downstream of 4th Street, a total distance of about 13,530-feet. The downstream portion of this segment has a bottom width of 40-feet; the upstream portion has a bottom width of 50-feet. Side slopes are 1V:3H throughout this segment. The second segment begins near Austin Avenue (note an unimproved segment lies between the improved segments) and extends a distance of about 1,670-feet downstream. This segment of the channel has a bottom width of 30-feet, and side slopes of 1V: 3.5H (left bank) and 1V:3H (right bank). This alternative would require the modification of the 14th Street Bridge by adding four 7x9-foot barrels to the existing box culverts (five 10x10-foot). Several water and sewer line relocations, in addition to other utilities would also have to be relocated. The project first cost was estimated at $3,798,400 (January 1994 price level). Annual costs and expected annual benefit were estimated at $356,700 and $1,167,600, respectively. The benefit-cost ratio was 3.3 to 1.0. Accordingly, a hydraulic channel improvement on Willis Creek warranted further investigation.

City Officials expressed the concern that the FM Road 2126 bridge, which crosses Pecan Bayou about five miles downstream of U.S. Highway 377, was an obstruction and thus, creating a backwater effect. The substantial roadway embankments, on both the left and right side of the channel, essentially block most of the overbank flow areas, thereby preventing storm water from effectively passing beneath the bridge. These embankments do not affect the capacity of the waterway during common storm events, but cause a significant increase in the water surface elevation during rare events. However, because of the distance upstream to the damage centers within the city of Brownwood, this increased water surface dissipates to only a few hundredths of a foot at Woodson Road. Preliminary investigations revealed that the cost of increasing the capacity of this bridge would not be justified by the negligible reduction in flood damages for such rare flood events in the study area. Therefore, this alternative was not studied in detail.

ALTERNATIVES INVESTIGATED

As a result of the previous screening of alternatives, specific alternatives were identified as warranting further study on Pecan Bayou and Willis Creek.

Pecan Bayou

Based on the initial screening of nonstructural and structural alternatives, only a hydraulic channel improvement was identified as warranting further study. A nonstructural plan was investigated through an array of alternatives but was not determined economically feasible in complying with planning objectives and constraints of this study. Additionally, permanent evacuation was not desired by the city of Brownwood given the significant number of commercial properties located in the frequently flooded areas. In addition, an alternative, not previously discussed, the removal or modification to the Riverside Park dam, was investigated. Presented below is the result of the additional detailed investigation of these alternatives.

Removal or Modification to Riverside Park Dam

As previously discussed, the advent of flooding along Pecan Bayou occurs when, during storm events, the dam impedes flow causing flood water to break out of the channel upstream of the dam, and inundate the developed areas. However, the impact of removing the dam on the flood

profile was not investigated in any detail. The city of Brownwood would not support the removal of the dam and the associated adverse impacts to Riverside Park. Therefore, removal of the dam was not considered further.

In an attempt to provide greater conveyance over the dam, the potential for widening the top width of the dam (and subsequently the channel) was investigated. Preliminary results revealed that only marginal reductions in flood damages could be achieved by widening the dam. Consequently, modifications to the dam were not considered further.

Hydraulic Channel Improvements

As previously discussed, a hydraulic channel improvement was determined to be feasible on Pecan Bayou during the reconnaissance study. The objective of the hydraulic channel improvement is to produce improved tailwater conditions downstream of the dam thereby minimizing the amount of flow leaving the channel upstream of the dam.

A re-analysis of the original Pecan Bayou channel improvement alternative produced significantly different results. This alternative, as seen in Figure 5, consisted of a grass-lined channel beginning at U.S. Highway 377 and extending downstream a distance of 7,500 feet. The channel would have a bottom width of 50-feet with side slopes of 1V:3H. Excavation of both the channel side slopes and bottom would be undertaken. The banks would be steeper at the Woodson Road Bridge to enable the improved channel to have a smooth transition in and out of the bridge; further, the existing bridge concrete columns would be encased to compensate for the channel excavation under the bridge. Utility relocations would also be required. The current estimated total project cost and annual cost of this alternative is $3,670,700 and $277,000, respectively. Expected annual benefits are estimated at $4,300, for a benefit cost ratio of 0.02.

Based on the analysis, the hydraulic channel improvement on Pecan Bayou will not be feasible. The estimated flood damage reduction benefits associated with a channel improvement have been drastically revised downward since the reconnaissance study. The reconnaissance study estimates of flood damage reduction benefits were determined with limited information and analyses, and outdated methodologies. During this feasibility study, the analyses benefited from additional, detailed information. Further, improvements in the hydrologic, hydraulic, and flood damage estimate models used in this feasibility study identified inaccuracies in the reconnaissance study estimates. Once corrected, it became clear the channel improvement would not significantly reduce flood damages.

While a larger channel may potentially produce greater flood damage reduction benefits, the larger channel will also have considerably greater construction costs. Assuming environmental mitigation costs could be reduced by limiting excavation to single, alternating-bank as well as by avoiding the channel bottom by using a “terrace”, realistically the incremental increase in benefits, relative to the incremental cost increase, would not be sufficient to raise the benefit cost ratio to 1.0. While potential benefits related to the avoidance of traffic disruption costs, flood fighting and recovery costs, and public damages are not quantified, they are not likely sufficient to provide economic feasibility to this alternative. Therefore, a hydraulic channel improvement on Pecan Bayou was eliminated from further consideration.

Overflow Swale

In order to provide additional conveyance, an overflow swale was also investigated. The swale investigated consisted of a grass lined channel beginning at an oxbow on the Pecan Bayou slough immediately north of Woodson Road that rejoins the main stem of Pecan Bayou about 8,600-feet downstream as shown in Figure 6. The swale has a bottom width of 100-feet, with side slopes of three horizontal to one vertical. Normal flows would continue to flow through Pecan Bayou slough, until about the 2-year frequency event which would spill into the swale and pass through the study area without causing any property damage. The swale would have a very low slope to the point where it rejoins Pecan Bayou, and then it would need to drop quickly into the existing channel. This portion of the new channel would need to be protected from erosion by the use of concrete riprap on the banks and invert. Figure 6 displays this alternative.

FIGURE 5 GOES IN HERE

FIGURE 6 GOES IN HERE

The estimated total and annual cost of the swale alternative is $8,951,500 and $626,000, respectively. Expected annual benefits are estimated at $120,500, representing a reduction in flood damages of about 12%. The resulting benefit-cost ratio is 0.19, well below that required for economic feasibility. Other swale sizes (bottom-widths) were also investigated, with similar results. The highest benefit-cost ratio obtained was 0.4.

Given the inability to identify a feasible alternative that meets the planning objectives and avoids the planning constraints, while addressing the technical, environmental, social and economic criteria as evaluated by the concepts of completeness, effectiveness, efficiency and acceptability, an alternative for Pecan Bayou cannot be identified as depicted in Table 6. Consequently, further detailed investigations for this study area will not be conducted.

Table 6

Economic Analysis of Structural Plans

($1000's, May 2000 prices and levels of development)

Alternative Bottom-width	Residual Damages	Flood Reduction	Insurance Subsidy	Annual Benefits	Annual Costs	Net Benefits	B/C Ratio
No Action	$ 735						
PB50	$ 729	$ 5.9		$ 5.9	$ 277.0	$ (271.1)	0.02
AS10	$ 647	$ 88.1		$ 88.1	$ 245.0	$ (157.4)	0.36
AS50	$ 631	$ 104.1	$ 0.1	$ 104.3	$ 436.0	$ (331.9)	0.24
AS100	$ 615	$ 120.1	$ 0.4	$ 120.6	$ 626.0	$ (505.5)	0.19

PB = Pecan Bayou AS = Adam Branch / Swale

Willis Creek

Based on the initial screening of nonstructural and structural alternatives, permanent evacuation and hydraulic channel improvement are two alternatives identified as warranting further study. A nonstructural plan was investigated through an array of alternatives but was not determined economically feasible in complying with planning objectives and constraints of this study. Presented below are the results of the additional detailed investigation of these alternatives.

Permanent Evacuation

Three different permanent evacuation scenarios were investigated on Willis Creek. The first called for the acquisition and removal of all (54) structures within the 50% ACE flood plain, the second was the acquisition and removal of all (144) structures within the 10% ACE flood plain, and the third was the acquisition and removal of all (274) structures within the 1% ACE flood plain. As shown in Table 7, the resultant benefit-to-cost ratios for the 10- and 1 percent zones were below unity and the ratio for the 50 percent zone had relatively minimal net benefits. There was no interest in pursuing lower level or partial protection for smaller number of structures without affecting "community cohesion". Basically stated, a permanent evacuation alternative cannot be recommended which removes only a portion of the affected structures while leaving a number of structures within the same flood plain in the study area. Therefore, permanent evacuation was eliminated from further consideration.

Table 7

Benefits of Nonstructural Alternatives on Willis Creek

($1000's, May 2000 prices and levels of development)

Flood Event	No.	Flood Free Value	Demolition Costs	Economic Costs	Annual Benefits	Annual Costs	Net Benefits	BCR	Financial Costs
0-50%	54	$ 4,387.6	$1,062.3	$ 5,450.0	$ 389.0	$ 384.0	$ 5	1.0	$1,527.0
0-10%	144	$ 9,186.7	$1,218.3	$ 10,405.0	$ 776.7	$1,072.0	($672)	0.7	$3,198.0
0-1%	274	$25,192.3	$8,661.4	$ 30,854.0	$1,033.0	$2,234.0	($1,201)	0.5	$5,661.4

Hydraulic Channel Improvement

As previously discussed, a hydraulic channel improvement was originally determined to be economically feasible on Willis Creek during the reconnaissance study. The primary objective of the hydraulic channel improvement was to contain flood flows within the banks of the creek and minimize losses. An update of the original analysis of the Willis Creek channel improvement alternative investigated a grass-lined channel beginning near Asbury Street and extending about 4,800-feet downstream of Austin Avenue. The total length of the improvement would be approximately 16,280-feet through the natural channel. The channel bottom width would be 45-feet with side slopes of 1V:3H. The initial center line for the improved channel would also be located such that the alignment would minimize adverse impacts to ecological resources as well as occupied land, i.e., back yards of those homes located adjacent to the creek through the use of one-sided excavation to fullest extent possible. This channel improvement would require a modification to the 4th street and 14th street bridges culverts, and utility relocations, primarily consist of water, sewer, gas, electric, telephone, and cable. Erosion protection would also be required along portions of the improved channel. Figure 7 displays the hydraulic channel improvement alternative.

Flood Damage Reduction.

The channel was evaluated for bottom-widths of 10-, 25-, 45-, and 60-feet. Benefits quantified during these analyses were the reductions in damages to structures (residential and commercial) and their contents, and savings in flood insurance costs. These alternative plans would produce a damage reduction ranging from 47 percent to 97 percent based on planning level cost estimates. A summary of the residual damages and resulting benefits is presented in Table 8.

Table 8

Economic Benefits of Structural Plans for Willis Creek

($1000's, May 2000 prices and planning levels of development)

Alternatives	Residual Damages	Flood Benefits	Insurance Benefits	Total Benefits	% Damage Reduction
No Action	$ 956.7				
10-foot	$ 509.3	$ 447.3	$ 5.7	$ 453.0	47%
25-foot	$ 253.6	$ 703.0	$ 13.3	$ 716.3	75%
45-foot	$ 112.4	$ 844.2	$ 35.6	$ 879.9	92%
60-foot	$ 63.1	$ 893.5	$ 37.7	$ 931.1	97%

FIGURE 7 GOES IN HERE

IDENTIFICATION OF THE RECOMMENDED PLAN

Knowing that a structural measure would address the stated planning objectives and constraints, the initial channel configuration was refined to identify one configuration which would maximize the net benefits to be determined as the recommended plan. The identification of the recommended plan will be accomplished by varying bottom widths and altering the alignment to avoid known or potential ecological and cultural resources as well as other physical constraints such as contaminated material, bedrock, etc. As depicted in Table 9, a planning level economic analysis was performed on the four bottom widths of 10-, 25-, 45- and 60-feet to determine the greatest net benefits.

Table 9

Economic Analysis of Structural Plans For Willis Creek

($1000's, May 2000 planning prices and levels of development)

	10-foot	**25-foot**	**45-foot**	**60-foot**
Estimated First Cost	$3,765,600	$4,321,300	$5,978,700	$6,735,300
Construction Period (Months)	12	15	18	21
Investment Cost	$3,888,997	$4,499,271	$6,275,785	$7,127,892
Operation/Maintenance ($/Year)	$10,000	$12,500	$15,000	$17,500
Total Annual Charges	**$278,510**	**$323,146**	**$448,303**	**$509,635**
Total Annual Benefits	**$452,954**	**$716,276**	**$879,854**	**$931,200**
Net Benefits	$174,444	$393,130	$431,551	$421,565
Benefit-to-Cost Ratio	**1.6**	**2.2**	**2.0**	**1.8**

As shown, the 45-bottom width channel produces the greatest net benefits of $431,551 with total and annual projects costs of $5.9 million and $448,300, respectively. The plan would reduce expected annual damages by 92 percent; eliminate all the damages in the 11 percent ACE event and 90 percent of the damages caused by the 1-percent flood event. The resultant plan has a benefit-cost ratio of 2.0 to 1.0 and net benefits (annual benefits in excess of annual costs) of about $431,600. The optimization curve presented in Table 10 graphically depicts the net benefits associated with the channel and confirms the 45-foot channel as the selected alternative. Table 11 shows the number of structures in each flood zone following plan implementation and the number of structures saved in each flood zone following project implementation.

Table 10
Willis Creek
Channel Optimization

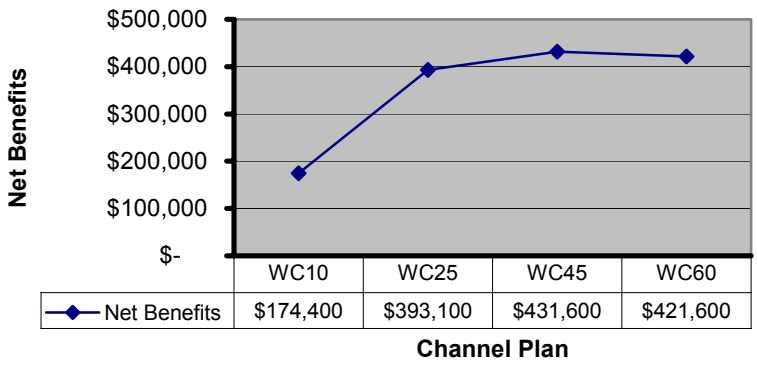


Table 11

Flood Zone Location of Structures

With and Without Project Summary

Alternative	10%	4%	2%	1%	0.2%
Existing	144	214	255	274	322
Number of Structures Remaining by Flood Event					
Willis A 10	59	122	201	235	306
Willis B 25	0	39	126	183	284
Willis C 45	0	6	12	30	240
Willis D 60	0	6	10	16	145
Total Structures Saved from Flooding					
Willis A 10	85	92	54	39	16
Willis B 25	144	175	129	91	38
Willis C 45	144	208	243	244	82
Willis D 60	144	208	245	258	177

Optimization

Further refinement was investigated to reduce adverse ecological impacts resulting from a hydraulic channel improvement. Although the channel centerline and alignment were set to minimize adverse ecological resources, additional resources could be avoided via a diversion channel. As shown in Figure 8, the diversion channel would begin about 1,200 feet downstream of 14th Street extending downstream a distance of 2,000 feet, and reentering Willis Creek about 500-feet upstream of 4th Street. The diversion channel is described as a grass-lined, trapezoidal channel having side slopes of 1V:3H and a 45-foot bottom width (given the 45-foot bottom width channel is proven to be the most efficient; no other bottom width for the diversion channel was investigated in detail). The effect of the diversion would be the avoidance of adverse impacts to the high quality riparian corridor in the area in question, as well as reducing environmental mitigation costs. The hydraulic channel improvement alternative up- and downstream of the diversion channel would remain the same. Table 12 displays a summary of the economic analysis of the hydraulic channel improvement alternative with the diversion for Willis Creek.

FIGURE 8 GOES IN HERE

Table 12

Planning Level Economic Analysis of Structural Plans For Willis Creek with Diversion

($1000's, May 2000 prices and levels of development)

	10-foot	25-foot	45-foot	60-foot	45-foot Diversion
Estimated First Cost	$3,765,600	$4,321,300	$5,978,700	$6,735,300	$5,942,400
Construction Period (Months)	12	15	18	21	18
Investment Cost	$3,888,997	$4,499,271	$6,275,785	$7,127,892	$6,237,681
Operation/Maintenance ($/Year)	$10,000	$12,500	$15,000	$17,500	$17,500
Total Annual Charges	**$278,510**	**$323,146**	**$448,303**	**$509,635**	**$445,672**
Total Annual Benefits	**$452,954**	**$716,276**	**$879,854**	**$931,200**	**$879,854**
Net Benefits	$174,444	$393,130	$431,551	$421,565	$434,182
Benefit-to-Cost Ratio	**1.6**	**2.2**	**2.0**	**1.8**	**2.0**

Based on the planning level economic analysis in Table 12, the 45-ft bottom width alternative with diversion provides the greatest net benefits comparatively among any alternatives evaluated in detail.

When updated with current costs and pricing data of May 2001 through an MCASES cost estimate, the total and annual project cost of the recommended plan with diversion channel is estimated at $7,961,900 and $572,800, respectively as indicated in Table 13. Significant Estimated First Costs were increased due to higher real estate costs when updated with current costs respectively. The resultant BCR is 1.6 to 1.0 with about $314,800 in net benefits. Table 14 presents the overall project performance accounting for risk and uncertainty. As shown, there is a 87 percent probability that the project would contain the 25-year or 4 percent ACE event. However, it should be recognized that the project is expected to *reduce* overall damages.

Table 13

Economic Analysis of Alternative with Diversion For Willis Creek

($1000's, May 2001 prices and levels of development)

	WC45 w/Diversion
Estimated First Cost	$7,961,900
Construction Period (Months)	18
Investment Cost	$8,342,600
Operation/Maintenance ($/Year)	$15,600
Total Annual Charges	**$572,800**
Total Annual Benefits	$887,600
Net Benefit	**$314,800**
Benefit-to-Cost Ratio	**1.6**

Table 14

Project Performance of Willis Creek Recommended Plan

	Expected Annual Target Stage Exceedence Probability		Long Term Risk (Years)			Conditional Non-Exceedence Probability by Event					
Target Stage	Median	Expected	10	25	50	10%	4%	2%	1%	.4%	.2%
1358	.007	0.017	.158	.349	.576	0.985	0.847	0.698	0.594	0.458	0.370

The following sections describe other affects of the hydraulic channel improvement.

Ecological Resources

The effects to ecological resources were quantified during the analysis of the various bottom widths investigated. Table 15 displays a summary of the habitat and acres affected.

Table 15

Habitat and Area Effected

	Bottom Width				
	10-Feet	25-Feet	45-Feet	60-Feet	45-Feet w/ Diversion
Riparian	39.6 acres	39.6 acres	39.6 acres	39.6 acres	33.5 acres
Old Field	12.2 acres	17.4 acres	24.0 acres	29.1 acres	33.6 acres
Stream	15,000 feet	15,000 feet	15,000 feet	15,000 feet	13,000 feet

As seen Table 15, the adverse effects to the high-quality riparian habitat is maximized with the 45-foot bottom width channel improvement given the proximity of the habitat to the top of the channel bank. Additional adverse effects from a larger channel improvement are experienced only to the relatively lower-quality old-field habitat. The trade-off between reduced adverse effects to the riparian habitat at the expense of additional impacts to the old-field habitat is acceptable.

Threatened and Endangered Species

Threatened or endangered species were not identified in the study area or in the layout of the recommended plan. Therefore, they have no adverse bearing on the plan.

Cultural Resources

The hydraulic channel improvement alternative will not affect any historic buildings or structures. However, given the alluvial deposition throughout the study area, the potential to disturb buried archeological resources is high, regardless of the size or alignment of the channel. There have been numerous recordings of buried archeological resources within the study area. Cultural resource investigations will be required prior to construction. In the event resources are encountered, the channel alignment can likely be shifted to avoid disturbance of known resources if needed. However, substantial, significant resources may be encountered which may not be able to be completely avoided. In this unlikely event, the resources will require mitigation.

Hazardous, Toxic, and Radioactive Wastes

The initial site assessment, including reviews of the regulatory records and databases, aerial photographs, and interviews indicate the lack of a presence of apparent HTRW releases or CERCLIS sites in or near the study area. The one area of concern is located south of the creek, and west of 14th Street. This site is a Formerly Used Defense Site (Camp Bowie), and was used as a potential uncontrolled dumping site. An investigation of the site concluded that the area contained solid municipal waste. The investigation did not identify any hazardous material. While the initial indication is that the channel improvement alternative is not likely to disturb or impact the buried municipal waste, additional investigations may be required to determine the exact location (boundary) of the known waste. However, since this was a Federal facility, if any hazardous or contaminated materials are found, the responsibility for cleanup will fall to the Federal Government.

NATIONAL ECONOMIC DEVELOPMENT PLAN

The National Economic Development (NED) plan is that alternative which addresses the planning objectives and constraints, and having the greatest amount of net benefits, consistent with protecting the Nation's environment.

SELECTION OF THE RECOMMENDED PLAN

While the National Economic Development (NED) plan is initially identified as the Federally recommended plan, frequently the non-Federal partner will find it in their interest to pursue a plan that sacrifices some NED net benefit for additional contributions to other planning objectives. When the non-Federal partner prefers a plan that is not the NED plan, that plan is designated as the locally preferred plan.

After initial review of the recommended plan, the city of Brownwood requested a variation of the bank slopes from 1 vertical to 3.0 horizontal to 1 vertical to 3.5 horizontal for ease of maintenance. Review of this request revealed that this could easily be accomplished without having any impacts to the NED plan by narrowing the bottom width from 45 feet to 40 feet. It was reviewed and determined that the quantity differences would be negligible. With this, the recommended plan is also the locally preferred plan.

This section provides further details on the Recommended Plan, as determined in the preceding chapters of this report. Detailed cost estimates were developed with May 2001 price levels and is presented as categorized in the various MCACES accounts. Federal and non-Federal cost apportionment responsibilities are also present.

DESCRIPTION

As described above in the NED plan, the recommended plan is a flood damage reduction project consisting of 15,680 feet of hydraulic channel improvement on Willis Creek within the city of Brownwood. The improvement consists of a grass-lined trapezoidal channel with side slopes of 1 vertical to 3.5 horizontal and a bottom width of 40 feet with pilot channel. The channel depth will vary between 4 and 11-feet with the top width varying between 40 to 135 feet. Alternating bank sloping will be utilized to minimize costs and environmental impacts while achieving the design slope angles. The upper segment of the improvement begins near Asbury Street, and extends approximately 6,400 feet downstream (about 1,200 feet downstream of 14th Street.) At this point, a diversion channel will be excavated across an open field, reconnecting to Willis Creek about 2,000 feet downstream (approximately 500 feet upstream of 4th Street). The improved channel continues downstream, approximately 7,880 ft to the terminus of the plan approximately 1600 feet east of Quail Creek Court. The proposed improvement will primarily follow the existing creek alignment with the exception of several creek bends that will be bypassed and the 2000-foot diversion channel between 14th Street Bridge and 4th Street Bridge. The bypassed creek bends will be preserved within the channel with base flows to provide for deeper pools and ripples to act as wetlands and provide wildlife habitat. Approximately 96 acres of reforestation will be undertaken to mitigate

habitat removed by the channel excavation. The improvement will also require box culvert modifications to the 14th Street and 4th Street bridges, side slope modifications at the Austin Avenue Bridge, and some storm drain and utility relocations. Riprap will be placed at the bridge approaches for erosion protection.

MAJOR PROJECT FEATURES

Structures

The City will be responsible for removing and/or relocating all miscellaneous structures, small sheds, and detached buildings that are within the limits of improvement prior to the award of the Willis Creek Project.

Roads

No roads will be relocated, however modifications to the box culverts at 4th Street and 14th Street will require road and culvert improvements during construction. Austin Avenue road and bridge will not be impacted.

Utilities

Various utility lines will be impacted throughout the improvement along Willis Creek. Approximately 565-feet of various storm drains (reinforced concrete and galvanized pipe), 1350-feet of sanitary sewer, 115-feet of gas lines, and 415-feet of water lines will need to be extended and/or relocated.

Modifications

In order to minimize constriction of flow, the existing box culverts at 4th street and 14th street will need to be enlarged. This consists of adding 3 additional 10' wide x 8' deep box culverts to the existing culverts at 4th street and removing the existing culverts at 14th street and adding an 8 barrel 10' x 10' box culvert. No structural modifications are required at Austin Avenue bridge, however some side slope modifications will be required for the approach transitions. Riprap will be placed at the bridge approaches for erosion protection.

Disposal Areas

The city of Brownwood has established a location for the excess excavated and waste materials. The primary site for the disposal of materials from Willis Creek is the local city of Brownwood landfill located approximately 0.75 miles southwest of the intersection of F.M. 2126 and F.M. 45. This 33 acre disposal site will accommodate the estimated 260,000 cubic yards of overburden material which has been initially determined free of any HTRW concerns. The haul distance from project site to the landfill will vary from 3-5 miles depending on the specific staging areas. Disposal of excavated materials to this site does not pose any adverse cultural, environmental, or HTRW concerns.

Construction Access and Staging Areas

Temporary construction access and staging areas for the construction contractor will consist of three locations along the channel improvement to move in conjunction with the construction progress. The upstream segment will have 1.9-acre strip for temporary construction access from Highway 377 to the edge of Stonebrook Court and a 0.8-acre temporary staging area. The mid-channel segment will be located on the west side of the 4th Street bridge and have a 0.6 acre strip for temporary road easement, a 0.6 acre temporary work area easement for staging purposes. The downstream staging area is located approximately 800 ft from the end of the channel improvement and will have a 0.5-acre strip for temporary road easement and 1.6 acres for temporary work staging easement. Temporary easement access to this staging area will tie into the corner of Wood Ave and Cottage Street.

Real Estate Requirements

The project lands lies within the city limits of Brownwood. The Recommended Plan will require a maximum of 189.2 acres of Lands, Easements, Right of Ways, Relocations, and Disposal (LERRDs) areas to be obtained. This includes 60 acres for channel improvement easement, 1.9 acres for temporary work area easements, 4.1 acres for road access easement, and 123.2 acres for environmental mitigation.

During this study, Gross Appraisals were performed on 123.2 acres identified for mitigation acquisition. Further refinement of the sites by the U.S. Fish and Wildlife Service concluded that only 96 acres were actually required for environmental mitigation purposes. This difference in acreage is relatively minor in cost and does not alter the overall feasibility of the Recommended Plan. Implementation of this proposed project does not necessitate the relocation of any residences.

Recreational Features

The recommended plan is a hydraulic channel improvement project for the purpose of flood damage reduction project and the city of Brownwood did not have interest in pursuing any recreational features. Therefore, this study does not contain any recreational benefits, however future considerations by the city could offer walking trails through the mitigation areas once the site is established and there are no adverse impacts to the mitigation areas.

Environmental Mitigation

Good environmental design and engineering practices have identified a number of environmental design features, which are incorporated into the project. Every effort has been made to avoid or minimize adverse impact to aquatic and terrestrial habitat concurrent with achieving the flood damage reduction objectives. Impacts to ecological resources were evaluated during the plan formulation process. Mitigation requirements were initially identified. The final mitigation requirements, including location, size, quality, etc… were coordinated with the U.S. Fish and Wildlife Service and the city of Brownwood.

In the draft Fish and Wildlife Coordination Act Report, dated 23 May 2001, the U.S. Fish and Wildlife Service recognized that the Willis Creek Flood Damage Reduction Project would adversely impact high quality terrestrial and aquatic resources. For adverse impacts to terrestrial resources, the Service recommended the acquisition and management of approximately 96 acres of mitigation lands consisting of grassland/old fields and bottomland hardwoods contiguous to the project area. In mid-September 2000 and in cooperation with the U.S. Fish and Wildlife Services, several sites were identified as potential areas for mitigation in and around the City of Brownwood. These sites are noted below in Table 16.

Table 16
Proposed Terrestrial Habitat Mitigation Sites
Identified in Brownwood.

	Habitat Composition	
Identified Mitigation Sites	**Old Field** (Acres)	**Riparian Forest** (Acres)
Airport	70.5	190.5
Willis Creek Bendway	7.0	7.8
Adams Branch East	60.9	37.5
Pecan Bayou West	12.2	6.0
Riverside Park North (Craven's Estate)	41.3	20.1

The recommended plan for mitigation for adverse impacts to the terrestrial resources of Willis Creek resulting from the recommended channel modification would consist of converting 80 acres of grassland/old field to bottomland hardwood habitat and restoring 16 acres of native grasslands. As listed above in Table 16 and shown in Figure 10, the highest preference of these identified mitigation sites is located at the Brownwood Municipal Airport and Riverside Park North (Craven's Estate). This conversion of grassland/old field habitat would be done by planting a minimum of 100 hardwood, mast-producing trees and 50 fruit-bearing shrubs. Restoration of the native grasslands would require the planting of a variety of native grass and forb species that are native to Texas and have proven wildlife food and cover value. Planting a mixture of native grasses and forbs to stabilize soils on newly constructed channel side slopes would also be performed. Several bypassed bends will be planted with native grasses and forbs adapted for inundations and suitable for wildlife. Construction of a base flow or low-flow channel (approximately 15 feet wide and 2.5 feet deep) that mimics the streams' original sinuosity, the placement of ten, low-water retention structures at base grade along the stream to create pool habitat, and the planting of native aquatic macrophytes in the constructed base flow channel would be performed to compensate for the unavoidable impacts to aquatic resources.

Operations and Maintenance procedures would consist of limited or restricted mowing and other intensive maintenance activities on mitigated lands whenever possible to the late fall and winter months in order to provide optimum wildlife food and cover during the spring and summer reproductive season. No mowing should occur on the designated wildlife mitigation lands following successful reestablishment of woody vegetation. Fencing was not included in the cost study costs of this estimate since there was not an anticipated disturbance from livestock or human activities. An Operations and Maintenance Manual will be prepared by the Fort Worth District, in coordination with the U.S. Fish and Wildlife's Coordination Act Report, after completion of the project to provide maintenance requirements and procedures for the mitigated areas to be performed by the city of Brownwood.

IMPACTS OF THE RECOMMENDED PLAN

Flood Damage Reduction

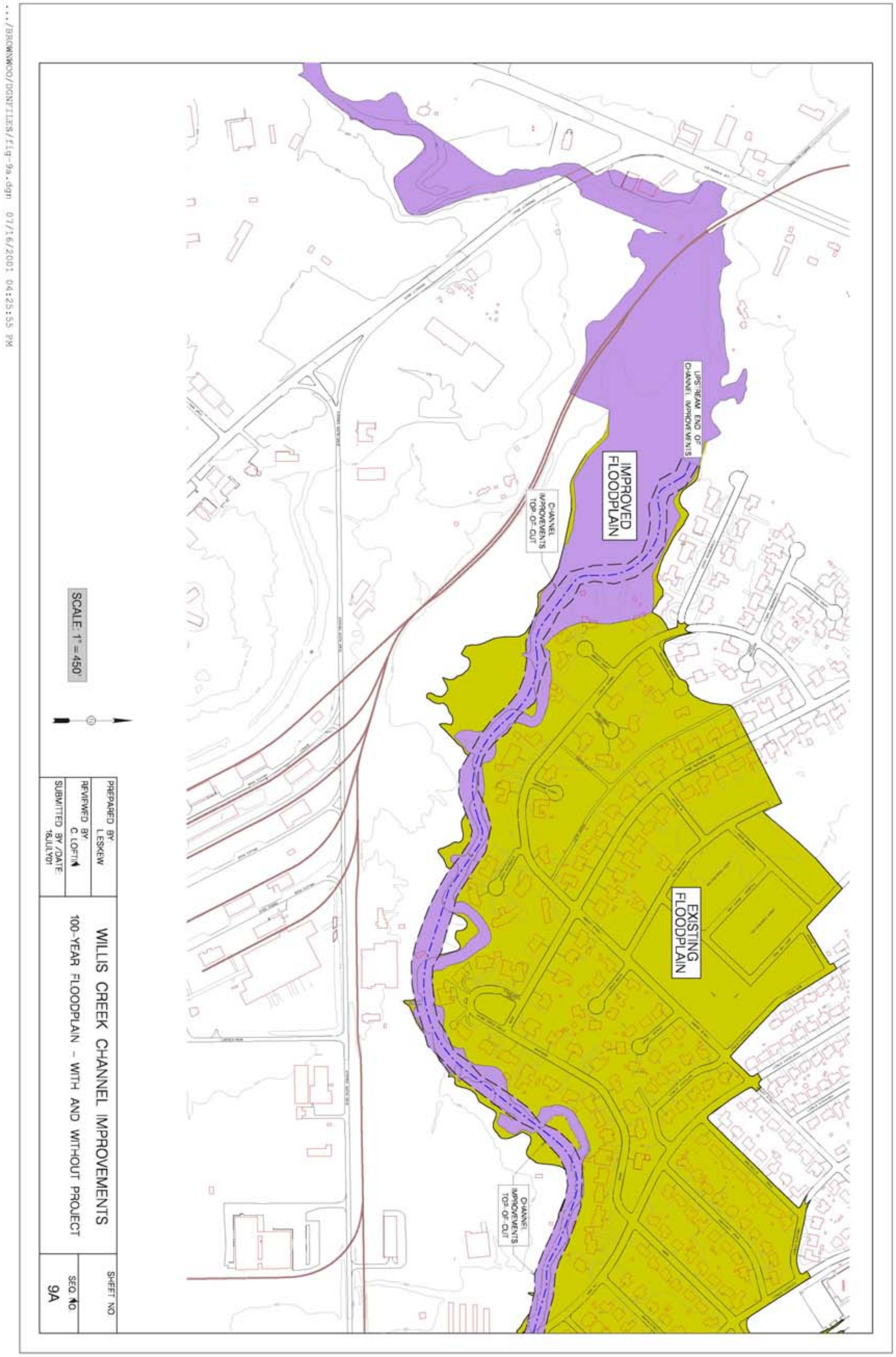
The Recommended Plan would reduce annual flood damages by 92% with an estimated total project cost of $7,961,900 and an annual project cost of $572,800. The Plan has a benefit-to-cost ratio of 1.6 with net benefits of $314,800. The Plan would eliminate all damages within the 10 percent (10 year) floodplain and almost 60 percent damages within the 1 percent (100 year) floodplain. Figures 9A, 9B, & 9C illustrate the Recommended Plan with and without project conditions for the 1 percent floodplain.

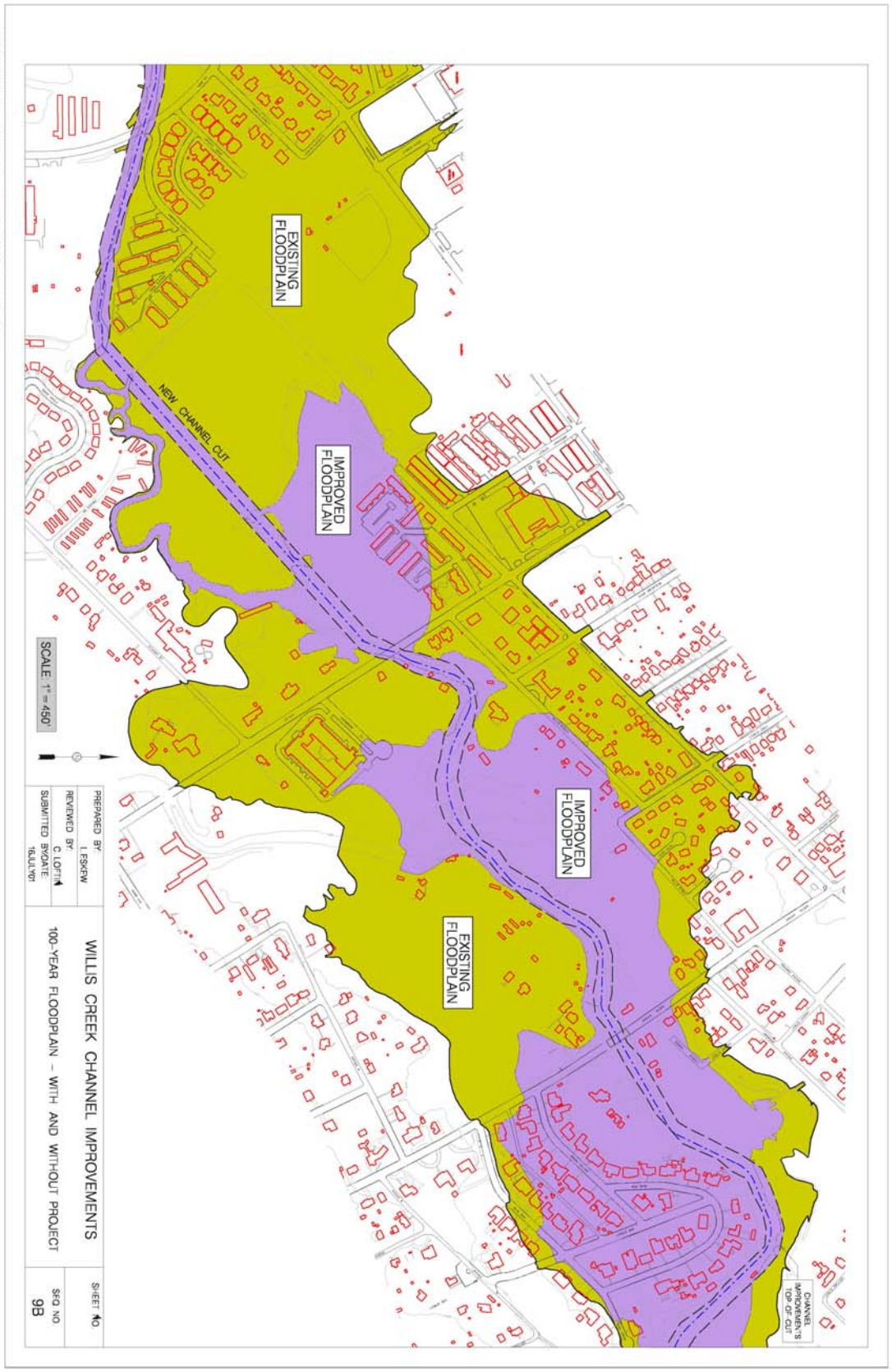
Hazardous, Toxic, and Radioactive Wastes

Previous investigations channel site indicates that the current alignment of the Recommended Plan will not encounter any hazardous, toxic, or radiological waste. As such, no additional investigations will be required. However, should the final alignment of the channel shift to the south towards the former Camp Bowie landfill area, additional investigations will be required to determine the exact extent of the landfill.

Land Use

In accordance with Section 202(c) of the Water Resources Development Act of 1996, within one year of implementation of the proposed project, the City of Brownwood would be required to submit an Floodplain Management Plan (FPMP). Measures in the FPMP would include restrictions on any business or residential development in the floodplain of Willis Creek. Under these restrictions, land use in the floodplain would not be further adversely impacted as a result of implementing the recommended plan.


.../BROWNWOO/DGNFILES/fig-9a.dgn 07/16/2001 04:25:55 PM
UPSTREAM END OF CHANNEL IMPROVEMENTS
IMPROVED FLOODPLAIN
CHANNEL IMPROVEMENTS TOP-OF-CUT
EXISTING FLOODPLAIN
CHANNEL IMPROVEMENTS TOP-OF-CUT
SCALE: 1" = 450'
PREPARED BY: LESKEW
REVIEWED BY: C. LOFTIN
SUBMITTED BY /DATE: 16JUL'01
WILLIS CREEK CHANNEL IMPROVEMENTS
100-YEAR FLOODPLAIN - WITH AND WITHOUT PROJECT
SHEET NO.
SEQ. NO.
9A


EXISTING FLOODPLAIN
NEW CHANNEL CUT
IMPROVED FLOODPLAIN
IMPROVED FLOODPLAIN
EXISTING FLOODPLAIN
SCALE: 1" = 450'
CHANNEL IMPROVEMENTS TOP OF CUT
PREPARED BY: I. FISKEW
REVIEWED BY: C. LOFTIN
SUBMITTED BY: DATE: 16JUL'01
WILLIS CREEK CHANNEL IMPROVEMENTS
100-YEAR FLOODPLAIN – WITH AND WITHOUT PROJECT
SHEET NO
SEQ NO 9B

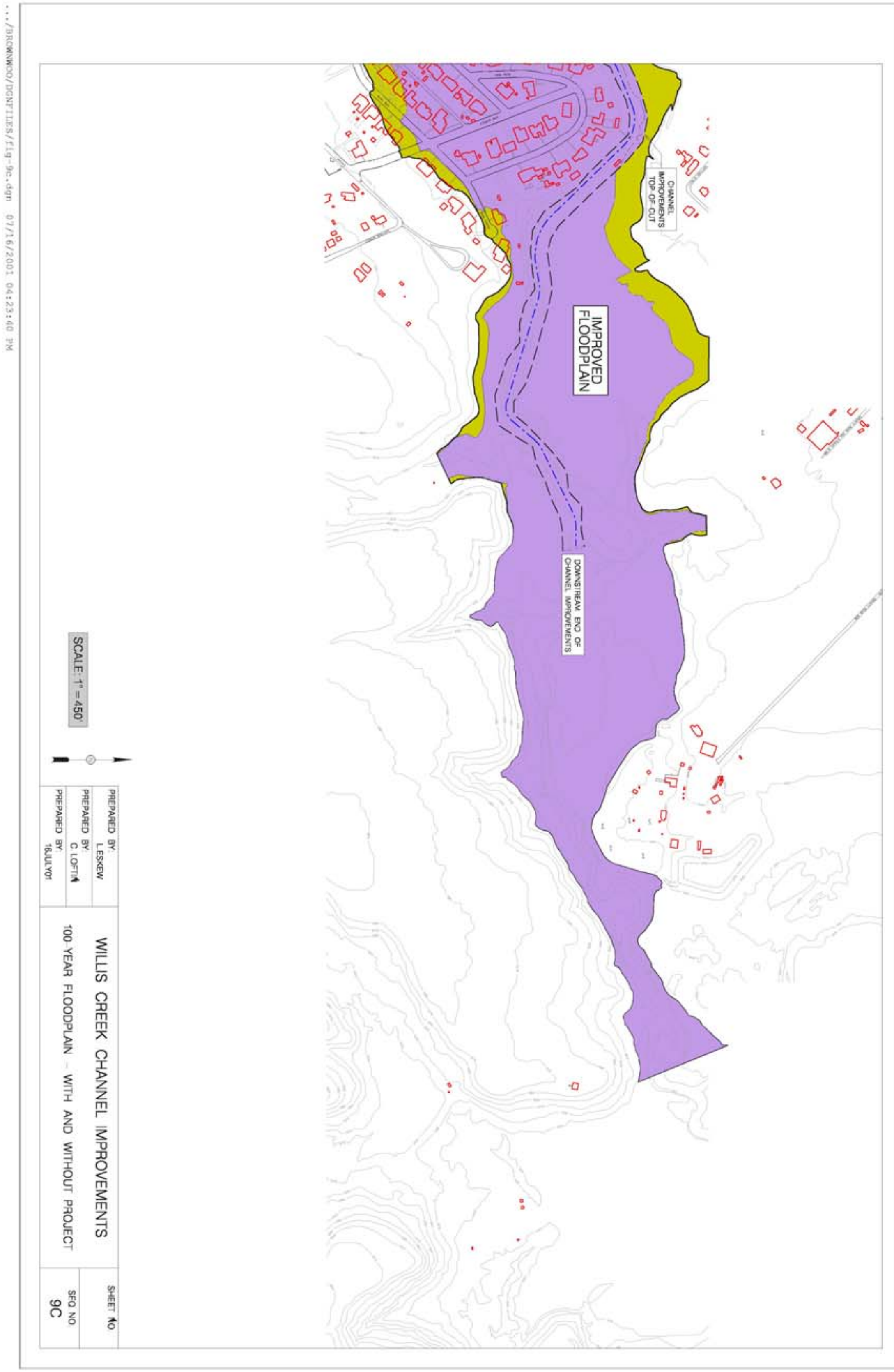

.../BROWNWOO/DGNFILES/fig-9c.dgn 07/16/2001 04:23:40 PM
CHANNEL IMPROVEMENTS TOP-OF-CUT
IMPROVED FLOODPLAIN
DOWNSTREAM END OF CHANNEL IMPROVEMENTS
SCALE: 1" = 450'
PREPARED BY: L.ESKEW
PREPARED BY: C. LOFTIN
PREPARED BY: 16JUL'01
WILLIS CREEK CHANNEL IMPROVEMENTS
100-YEAR FLOODPLAIN - WITH AND WITHOUT PROJECT
SHEET NO
SEQ NO
9C

FIGURE 10 GOES IN HERE

Air Quality

Construction activity associated with the implementation of the recommended would result in temporary adverse impacts to air quality from fugitive dust production, smoke, and construction vehicle emissions. There would be no stationary emitting sources and no on site storage of petroleum or petroleum based by-products to cause additional negative impacts to air quality. Disposal of cleared vegetation or other debris by burning during the construction would be allowed only as permitted by the TNRCC. Maintenance activities required for the recommended plan would contribute small amounts of additional mobile air emissions.

The reduction in tree canopy area and other perennial and annual vegetation from clearing activities for hydraulic channel construction would result in negative impacts through elimination of biogenic sources that remove regulated gaseous air pollutants.

Water Quality

Implementation of this alternative would result in short- and long-term adverse impacts to the water quality of Willis Creek. Short-term impacts would result from the movement of construction vehicles associated with excavation and grading activities in and around the Willis Creek channel. These activities would generate suspended sediments in the water column and increase turbidity levels. Suspended sediments would shade and silt over oxygen producing phytoplankton and aquatic plants and suppress water dissolved oxygen levels. Long-term impacts to water quality would result from removal of vegetation in the riparian corridor surrounding Willis Creek. Removal of the Willis Creek tree canopy would reduce the amount of water shading and would cause increases in water temperatures. At a higher temperature, water is less capable of holding dissolved oxygen. Consequently, annual average dissolved oxygen concentrations in Willis Creek would be lower because of higher water temperatures. Removal of the other components of the Willis Creek riparian corridor would adversely compromise the ability of the riparian system to contribute organic nutrients to the stream ecosystem and adversely impact the riparian corridor's ability to filter out nutrients or noxious chemicals from the watershed. Implementation of a restrictive FPMP would moderate some of the adverse impacts resulting from the loss of the riparian corridor by limiting floodplain development and associated increases in the concentrations of nutrients or noxious chemicals that would enter the Willis Creek ecosystem. Additional adverse impacts to water quality would be minimized through the development and implementation of a National Pollution and Discharge Elimination System (NPDES) Storm Water Pollution Prevention Plan (SWPPP) that require provisions for corrective and implementable measures to prevent pollutants from entering Willis Creek during a storm event that would occur during and after construction activities.

Aquatic Resources

Construction of a recommended plan would adversely impact approximately 13,336 linear feet of non-wetland jurisdictional waters of the United States. Adverse impacts to the aquatic resources of Willis Creek would occur through generation of poor water quality, removal of aquatic habitat, and direct mortality. Implementation of this alternative would create water quality and habitat conditions that would be incapable of supporting many sensitive aquatic plants, invertebrates and vertebrates. Eventually, the aquatic species architecture in Willis Creek would resemble that of a disturbed environment. A main characteristic of a disturbed environment is low species diversity and little aquatic habitat. Aquatic species capable of surviving in a disturbed environment would eventually dominate the Willis Creek system. The adverse impacts of implementing this alternative would be moderated through avoiding areas of the creek in the bends and maintaining base water flow through the preserved areas during normal flow periods. The avoidance action would help to maintain the overall aquatic species diversity by providing refugia with environmental conditions capable of supporting sensitive aquatic species. Of the alternatives evaluated for the Willis Creek project, this alternative avoided the greatest abundance of aquatic habitat consistent with providing the necessary level of flood protection.

Terrestrial Resources

Construction of a recommended plan would adversely impact plant and animal terrestrial resources inhabiting the approximately 15.9 acres of old field habitat and 31.7 acres of forested riparian habitat along Willis Creek. Adverse impacts to terrestrial resources would occur through the removal of critical habitat essential to complete life cycle requirements and by direct mortality. The abundance and diversity of wildlife found in an area is the result of the habitat available for nesting, foraging, shelter, reproduction and rearing of young. Removal of the old-field and riparian habitat would result in a reduction in the number and diversity of terrestrial wildlife species present. The reduction in the abundance and diversity of habitat resulting from implementation of this alternative would generate conditions unable to support some plant and wildlife species. With the removal of habitat, the terrestrial plant species composition along Willis Creek would change to one more characteristic of a disturbed environment, dominated by a few species that could tolerate the new environmental conditions. Of the alternatives evaluated for the Willis Creek project, this alternative avoided the greatest abundance of terrestrial habitat consistent with providing the necessary level of flood protection. Avoidance of some of the riparian habitat in the creek bends would help to preserve some wildlife species; however, isolated pockets of wildlife habitat are less effective in maintaining wildlife diversity than an intact riparian corridor. Approximately 96 acres of reforestation and mitigation would be implemented in the watershed to replace that habitat lost through channel excavation. In addition, several bypassed bends will be planted with native grasses and forbs adapted for inundations and suitable for terrestrial resources. The primary sites identified for wildlife habitat were along the upstream reach of Willis Creek, the cutoff section near the diversion channel, and areas along the Riverside Park along Pecan Bayou.

ENVIRONMENTAL COMPLIANCE

Section 404 – Clean Water Act

The proposed project has been reviewed in accordance with Section 404(b)(1) guidelines (40 CFR Part 230) promulgated by the U.S. Environmental Protection Agency pursuant to Section 404 of the Clean Water Act for evaluation of the discharge of dredged and fill material into waters of the United States. The possible consequences of the recommended plan have been considered in accordance with regulations published in 33 CFR Parts 320 and 330 and 40 CFR part 230. On the basis of the guidelines set forth in ER 1105-2-100 and 40 CFR Part 230 for a Section 404(b)(1) evaluation (Guidelines for Specification of Disposal Sites for Dredged or Fill Material), the recommended plan for the Willis Creek Flood Damage Reduction Project would be specified as complying with the inclusion of appropriate and practical conditions to minimize pollution or adverse effects to the aquatic ecosystem and to implement and abide by the mitigation plan in this document. The 404(b)(1) evaluation is presented at the end of the environmental appendix.

Section 401 – Clean Water Act

Section 401 of the Clean Water Act (33 U.S.C. 1341) requires that any activity which could result in a discharge of a pollutant into waters of the United States obtain a certification from the State in which the discharge would originate and that the discharge comply with applicable effluent limitations and water quality standards. The recommended plan for Willis Creek would be considered a Tier II project as detailed in the “Memorandum of Agreement Between the U.S. Army Corps of Engineers and the TNRCC. A Joint Public Notice for this project between the Corps and the TNRCC to inform the public and governmental agencies would be used to initiate a 30-day comment period for the TNRCC certification. This public review period would be the same one used for NEPA compliance. A decision of denial or approval of this project for Section 401 water quality certification would be rendered at the end of the public review.

Executive Order 11988 – Floodplain Management

Executive Order 11988, Floodplain Management, was considered during the planning of the proposed project. There are no practical alternatives to achieve the project purposes of flood damage reduction without working in the floodplain. Following project implementation, development of the Willis Creek floodplain would be managed. This would occur in accordance with Section

202(c) of the Water Resources Development Act of 1996, and the Federal requirement that within one year of project implementation, the city of Brownwood develop and submit an FPMP.

Executive Order 11990 – Protection of Wetlands

Executive Order 11990, Protection of Wetlands, was considered during planning of the proposed project. The recommended plan would not adversely affect or result in the loss of any wetland areas. The recommended plan would be in compliance with Executive Order 11990.

Executive Order 12898 – Environmental Justice

Executive Order 12898 provides that each Federal agency identify and address, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations in the United States. As proposed, recommended plan would not have disproportionate affects on minority or low-income populations.

Federal Threatened and Endangered Species

The recommended plan has been review by the U.S. Fish and Wildlife Service (See Appendix M). As proposed, the recommended plan would not adversely affect any Federal or State listed threatened, endangered, or special species or critical habitats.

Environmental Mitigation and Incremental Analysis

Every effort was made during the planning stages of this project to avoid or minimize adverse affects to terrestrial and aquatic natural resources. Unavoidable adverse affects by this project would be mitigated by replacement of lost natural resources with habitat of the same or greater functional capacity and quality. In mid-September 2000, with the cooperation of the U. S. Fish and Wildlife Service, several sites were identified as potential areas for mitigation in and around the city of Brownwood. A mitigation plan for adverse impacts to natural resources is jointly being developed between the Corps and the U.S. Fish and Wildlife Service.

The proposed mitigation for affected aquatic habitat would be to construct an earthen base flow channel in disturbed areas of Willis Creek. The base flow channel would be approximately 15 feet wide x 2.5 feet deep and mimic the streams' original sinuosity. Ten low-water retention structures would be placed at base grade along the stream to create pool habitat. Aquatic habitat in creek bends where a diversion channel is planned would be avoided. Base water flow would be maintained in these bend areas by constructing small dikes of low elevation across the inlets and outlets of the diversion channels. Further definition of the mitigation plan for aquatic habitat would occur during the development of project Plans and Specifications.

National Historic Preservation Act

The Recommended Plan would be in full compliance with the National Historic Preservation Act.

GENERAL AESTHETICS

Noise

It is expected that there would be short-term negative motorized noise during construction, however implementation of the Recommended Plan would add approximately 96 acres of new and improved forest habitat to the study areas. This would result in positive overall reduction of noise levels in the areas by buffering the sounds of traffic and general noises from the surrounding neighborhoods.

Lighting

Lighting is not included as part of the Recommended Plan. Therefore, there would be no adverse affects caused by lighting.

Traffic

There would be no long-term changes in traffic patterns with implementation of the Recommended Plan. Access would not be eliminated for any local residents. Short-term delays are to be expected during modification of the concrete box culverts at the 4th Street and 14th Street bridge crossings, but closure of the streets would not be warranted. There might be some temporary traffic inconveniences as trucks and equipment move along adjacent streets, but no more than short-term inconveniences would be expected.

Cultural Resource Impacts

No previous cultural resources assessment effort was performed within the project areas for this feasibility study. A previous reconnaissance visit in 1997 by a staff archeologist indicated a high potential for encountering archeological or architectural properties. Previous excavation efforts by others along Willis Creek and Pecan Bayou have also recorded archeological artifacts such as burned rock middens and Indian burial rock shelters. Eight archeological sites were recorded on Willis Creek in 1978 and 1980 and six additional sites recorded in 1987. None of the archeological sites nearest the project area has had the criteria for listing in the NRHP applied, but the majority of the sites recorded were reported as having some integrity and some with significant depth. The lower reach of Willis Creek nearest the confluence with Pecan Bayou will be of particularly high sensitivity for impacts to archeological properties as several archeological sites have already been identified in the area south of the water treatment plant.

While an inventory has not been completed for any of the project areas to determine the existence of standing historic buildings and structures, including any bridges crossing the project areas, the potential for such properties within the areas of potential effect exists. The likelihood of historic period archeological sites within the project limits appears marginal and the available historic data does not indicate the previous existence of buildings from an earlier period. The project area will require individual inventorying and possibly an NRHP assessment depending on the age, context, and design of the properties.

All cultural resources coordination, consultation, field investigations, and other efforts will need to be conducted in the Plans and Specifications phase prior to any construction in order to minimize design changes or delays created by mitigation responsibilities.

Real Estate Impacts

The project lands lies within the city limits of Brownwood and will basically follow the alignment of the existing channel in reshaping one or both sides of the banks as needed to obtain the proposed slope design. The Recommended Plan will require 214 acres of Lands, Easements, Right of Ways, Relocations, and Disposal (LERRDs) areas. This includes 60 acres for channel improvement easement, 34.9 acres for temporary work area easements for staging purposes (33 acres is for disposal), 4.1 acres for temporary road access easement, and 96 acres for environmental mitigation. The primary sites identified for environmental mitigation were along the upstream reach of Willis Creek, the cutoff section near the diversion channel, and areas along the Riverside Park along Pecan Bayou. Others secondary sites identified were along south Willis Creek, Pecan Bayou, and Adams Branch. Implementation of this proposed project does not necessitate the relocation of any residences, however acquisition of easements along the creek will be required in order to accommodate construction and operations and maintenance of the project.

Design Assumptions and Considerations

Design assumptions and considerations of the channel improvement will be based on the recommended plan as outlined in this report. No special design assumptions or considerations are required.

Construction Assumptions and Considerations

Construction duration of the channel improvement is estimated at is 18 months after award of the contract. No special assumptions or considerations are required.

ECONOMIC ANALYSIS

Cost Analysis - Project First Cost

The project first cost includes estimates for Lands and Damages, Planning, Engineering and Design, Road, Railroads, and Bridges, Channels and Canals, and Construction Management. Contingencies were added on items in accordance with the level of confidence associated with the item. Construction cost data was developed using material, equipment, and labor costs typical for work of this nature in the Brownwood area. Real estate costs were developed after the Gross Appraisal was completed.

Annualized Costs

The project first cost was converted to an annual basis, using a 50-year amortization period and the current applicable Federal interest rate of 6.375 percent. Accrued interest during the construction period was calculated to produce a total investment cost. The annualized cost for the Recommended Plan was used for computation of the benefit-cost ratio (BCR). A 50-year period of analysis was assumed, extending from 2003 to 2053.

Economic Summary

Listed below, in Table 17, is an Economic Summary for the Recommended Plan detail the Total Project Cost.

Table 17 Total Project Cost

Project Cost:	
Relocations	$ 602,900
Fish & Wildlife	$ 448,816
Roads, Railroads, & Bridges	$ 639,246
Channels and Cannels	$2,433,652
Total Construction Cost	$4,124,614
Land and Damages	$2,990,577
Planning, Engineering, & Design	$ 442,388
Supervision and Administration	$ 404,337
Total Project Cost	**$7,961,916**
Interest During Construction	$ 380,699
Total Investment Cost	$8,342,599
Construction Period (months)	**18**
Annual Cost:	
Interest (6.375%)	$ 531,841
Amortization (50-years)	$ 25,353
Operations and Maintenance	$ 15,600
Replacements	$0
Total Annual Cost	**$ 572,793**
Total Annual Benefit	**$ 887,617**
Benefit-Cost Ratio	**1.6**
Net Benefits	**$ 314,823**

As noted, the total economic cost of the Recommended Plan would be approximately $7,961,900. The plan would have annual cost of $572,794, total annual benefits of $887,793, net annual benefits of $314,824, and a BCR of 1.6.

Project Cost Sharing

The provisions of the Water Resources Development Act of 1996 (Public Law 104-303), approved October 12, 1996, stipulates cost sharing requirements which local sponsors must meet for the Federal Government to be involved with water resource projects. Cost sharing provisions for the flood control, ecosystem restoration, and recreational development purposes are outlined below.

Flood Damage Reduction

Under the provisions set forth in Public Law 104-303, as amended, the designated Sponsor would be required to formally approve the recommendations of the Interim Feasibility Report before initiating the Preconstruction, Engineering, and Design Phase of the project.

For non-structural flood control projects, the non-Federal cost would be 35 percent of total project flood control costs. The non-Federal sponsor would be responsible for 100 percent of the operations, maintenance, repair, rehabilitation and replacement costs of the project.

For structural flood control projects, the non-Federal requirements would consist of Land, Easements, Right of Ways, Relocations, and Disposal areas (LERRDs), plus 5% cash contribution must be at least 35%, but no more than 50% of the project cost.

Ecosystem Restoration

Public Law 104-303, as amended, states that the non-Federal cost for ecosystem restoration projects would be 35 percent of the total ecosystem restoration project costs. The non-Federal sponsor would be responsible for 100 percent of the operations, maintenance, repair, rehabilitation, and replacement costs of the project. The city of Brownwood did not have any interest in pursuing any ecosystem restoration features.

Recreational Development

The recommended plan for Willis Creek is a hydraulic channel improvement project for the purpose of flood damage reduction project and the city of Brownwood did not have interest in pursuing any recreational features. Therefore, this study does not contain any recreational developments, however future considerations by the city could offer walking trails through the mitigation areas once the site is established and there are no adverse impacts to the mitigation areas.

Operation, Maintenance, Repair, Rehabilitation, & Replacement

The Federal Government and the city of Brownwood will enter into a project cooperation agreement (PCA) in which the city would accept the project following completion of construction, and ensure operation, maintenance, repair, rehabilitation and replacement (OMRR&R), in accordance with Federal regulations. Annual OMRR&R costs are estimated at $15,600.00. This includes mowing (3 times yearly) to regulate grass height and reduce growth buildup, bi-annual fertilizing of the grass to maintain adequate groundcover and prevent erosion, annual herbicidal applications as needed to control woody growth, general maintenance & clean-up, and removal of sediment buildup throughout the channel. Mowing and other intensive maintenance activities on environmental mitigated areas should be restricted whenever possible to the late fall and winter months in order to provide optimum wildlife food and cover during the spring and summer reproductive season, and that no mowing should occur on the designated wildlife mitigation lands following successful reestablishment of woody vegetation. An Operations and Maintenance Manual would be prepared by the Fort Worth District after completion of the project, and periodic

inspections would be conducted in ensure that all required maintenance was being performed by the city of Brownwood.

PLAN IMPLEMENTATION

DIVISION OF RESPONSIBILITIES

Project Cost Apportionment

This section presents the appropriate sharing of costs between the Federal and non-Federal interests for the Recommended Plan. The total cost of this plan was estimated at $7,961,916. The Federal cost would total approximately $3,980,958 (50%), while the non-Federal cost would equal approximately $3,980,958 (50%).

The costs shown below, in Table 18, are based on standard requirements set forth in Public Law 104-303, as amended, for each of the project purposes. Under these laws, non-Federal interests would be required to furnish all lands, easements, rights-of-way, and disposal areas, and perform all relocations of bridges and utilities.

Table 18 Cost Apportionment

	Federal	**City of Brownwood**
Land, Easements, & Right of Ways		$ 2,990,577
Relocations		
Utilities		$ 602,900
Roads, Bridges, Railroads		$ 639,246
Channels	$2,433,652	
Fish & Wildlife Mitigation	$ 448,816	
Engineering and Design	$ 331,791	$ 110,597
Supervision and Administration	$ 323,470	$ 80,867
Subtotal	$3,537,729	$ 4,424,187
5% Cash Contribution	$ (398,096)	$ 398,096
Subtotal	$3,139,633	$ 4,822,283
Adjust for 50% of Project Cost	$ 841,325	$ (841,325)
Total Cost Sharing Apportionment	**$3,980,958**	**$3,980,958**

Non-Federal Responsibilities

Having considered the social, economic, environmental, and engineering aspects of providing a flood damage reduction project for the city of Brownwood, Willis Creek, a project to reduce flood damages has been identified and is in the overall public interest. Accordingly, the recommended plan, as described in this report, is recommended to be authorized for implementation with such modifications as the Chief of Engineers may find advisable, and in accordance with existing cost sharing and financing requirements. The total first cost of the project,

based on 2001 price levels, is estimated at $7,961,900, with annual operation, maintenance, and repair costs estimated at $15,600.00. The final non-Federal responsibilities will be detailed in the Project Cooperation Agreement. In addition, a Preconstruction Engineering and Design (PED) agreement will be executed for the project prior to preparation of plans and specifications. This recommendation is also subject to the nonfederal sponsor agreeing to comply with applicable Federal laws and policies, including the following requirements:

A. Provide a minimum of 35 percent, but not to exceed 50 percent of total project costs and further specified below:

B. Enter into an agreement which provides, prior to construction, 25 percent of preconstruction, engineering, and design (PED) costs;

C. Provide, during construction, any additional funds needed to cover the non-federal share of PED costs;

D. Provide, during construction, a cash contribution equal to 5 percent of total project costs;

E. Provide all lands, easements, and right-of-ways, including suitable borrow and dredged or excavated material disposal areas, and perform or assure the performance of all relocations determined by the Government to be necessary for the construction, operations, and maintenance of the project;

F. Provide or pay to the Government the cost of providing all retaining dikes, wasteweirs, and embankments, including all monitoring features and stilling basins, that may be required at any excavated material disposal areas required for the construction, operation, and maintenance of the project; and

G. Provide, during construction, any additional costs as necessary to make its total contribution equal to 35 percent of total project costs.

H. For so long as the project remains authorized: operate, maintain, repair, replace, and rehabilitate the completed project, or functional portion of the project, at no cost to the Government, in accordance with applicable Federal and state laws and any specific direction prescribed by the Government.

I. Grant the Government a right to enter, at reasonable times and in a reasonable manner, upon land with the local sponsor owns or controls for access to the project for the purpose of inspection, and, if necessary, for the purpose of completing, operating, maintaining, repairing, replacing, or rehabilitating, the project.

J. Assume responsibility for operating, maintaining, replacing, repairing, and rehabilitating (OMRR&R) the project or completed functional portions of the project, including mitigation features without cost to the Government, in a manner compatible with the project's authorized purpose and in accordance with applicable Federal and State laws and specific directions prescribed by the Government in the OMRR&R manual and any subsequent amendments thereto.

K. Comply with Section 221 of Public Law 91-611, Flood Control Act of 1970, as amended, and Section 103 of the Water Resources Development Act of 1986, Public Lay 99-662, as amended, which provides that the Secretary of the Army shall not commence the construction of any water resources project or separable element thereof, until the non-Federal sponsor has entered into written agreement to furnish its required cooperation for the project or separable element.

L. Hold and save the Government free from all damages arising from the construction, operation, maintenance, repair, replacement, and rehabilitation of the project and any project-related betterment, except for damages due to the fault or negligence of the Government or the Government's contractors.

M. Keep and maintain books, records, documents, and other evidence pertaining to costs and expenses incurred pursuant to the project to the extent and in such detail as will properly reflect total project costs.

N. Perform, or cause to be performed, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response Compensation, and Liability Act (CERCLA), 42 USC 9601-9675, that may exist in, on, or under lands, easements or right-of-ways necessary for the construction, operation, and maintenance of the project.

O. Assume complete financial responsibility for all necessary cleanup and response costs of any CERCLA regulated materials located in, on, or under lands, easements, or right-of-ways that the Government determines necessary for the construction, operation, or maintenance of the project. The Government shall assume complete financial responsibility for all necessary cleanup and response costs of any CERCLA regulated material within Federal properties.

P. To the maximum extent practicable: operate, maintain, repair, replace, and rehabilitate the project in a manner that will not cause liability to arise under CERCLA.

Q. Prevent future encroachments on project lands, easements, and right-of-ways, which might interfere with the proper functioning of the project.

R. Comply with the applicable provisions of the Uniform Relocation Assistance and Real Property Acquisitions Policies Act of 1970, Public Law 91-646, as amended by Title IV of the Surface Transportation and Uniform Relocation Assistance Act of 1987 (Public Law 100-17), and the Uniform Regulations contained in 49 CFR part 24, in acquiring lands, easements, and right-of-ways, and performing relocations for construction, operation, and maintenance of the project, and inform all affected persons of applicable benefits, policies, and procedures in connection with the said act.

S. Comply with all Federal and State laws and regulation, including Section 601 of the Civil Rights Act of 1964, Public Law 88-352, and department of Defense Directive 5500.11 issued pursuant thereto, as well as Army Regulation 600-7, entitled “Nondiscrimination of the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army”.

T. Provide 35 percent of that portion of total cultural resource preservation mitigation and data recovery costs attributed to structural flood control that are in excess of one percent of the total amount authorized to be appropriated for structural flood damage reduction.

U. Participate in and comply with applicable Federal floodplain management and flood insurance programs and comply with the requirements in Section 402 of the Water Resources Development Act of 1986, as amended.

SUMMARY OF COORDINATION, PUBLIC VIEWS, AND COMMENTS

PURPOSE OF PROGRAM

This Feasibility Study focused on the development of an economically feasible, environmentally acceptable, publicly supportable solution to the flooding problems within the city of Brownwood. Several meetings and conversations with city officials have been held with the various entities and interested citizens to share the latest possible information and to focus this study toward investigating the most viable alternatives. In addition, various public workshops and meetings were held in the study areas for the citizens to give input in the problems and possible solutions, as stipulated by Public Law 99-662 and Public Law 104-303.

PARTICIPANTS

Study participants worked closed over the study period in an effort to inform and involve the concerned citizens in the study area. The agencies involved in this effort included the Fort Worth District Corps of Engineers, city of Brownwood, and the United States Fish and Wildlife Service.

PUBLIC WORKSHOPS AND MEETINGS

On September 12 & 13, 1994, a public meeting was held during an extended city council meeting to receive input from the citizens on the future of the Willis Creek and Adams Branch and to discuss Federal participation for flood damage reduction opportunities.

On November 19, 1996, a Feasibility Study Public Workshop meeting was held in the city of Brownwood during an extended city council meeting to gather citizen input and to provide an overview of the Feasibility Study.

In 1998, a public meeting was held in coordination with an extended city council meeting to discuss the progress of plan formulation of Willis Creek and Adams Branch and to receive input from the citizens of Brownwood.

On June 26, 2001, a public meeting was held during a city council meeting to inform the city council and general public of the recommended plan and to visually show with and without project conditions for the 100 year flood event.

PUBLIC REVIEW

(To be completed following the public review period.)

FINANCIAL ANALYSIS – SOCIOECONOMIC EFFECTS OF PLAN IMPLEMENTATION

The potential economic and social effects from implementation of the Recommended Plan on the study area are comprised of the value of the long-term reduction in periodic flood damages, direct and indirect short-term income, and employment impacts of project construction. The permanent reduction in periodic flood damages would effectively increase the income available to floodplain property owners released from the financial burden inherent to residing in the floodplain.

To the extent that this additional disposable income is spent within the city, it would result in a local “multiplier effect”. Increases in business revenues, employment, and personal income rippling throughout the local economy as each new dollar brought in is spent and re-spent. Property values, and local tax revenues cold also increase as a general result since the public perception of the area would be improved by project implementation.

In addition, short-term employment effects associated with project construction would stimulate increased demand locally for construction materials and services. These expenditures would be expected to result in a positive multiplier effect on the local economy and would last for about two years.

Given the small scale of the Recommended Plan, the short-term impacts associated with construction would be temporary and insignificant relative to the overall local economy as a whole. Eventually, the only lasting economic and social effects of project implementation would be the benefits resulting from the permanent reduction in flood damages and the designation of the land for recreational and restoration purposes.

NON-FEDERAL FINANCIAL PLANNING

The purpose of strategic financial planning is to optimize the use of capital over time in response to long-term financial goals. The three principal elements involved include cost recovery alternatives, selection of the preferred financing alternative, and implementation of the cost recovery approach. Although financing decisions are ultimately the sponsors', the Corps of Engineers can assist in the decision making process through the provision of timely information on costs, benefits, and cost recovery opportunities. The sponsor is responsible for making arrangements to finance the project sufficiently in advance of construction to enable the project schedule to be met.

ABILITY-TO-PAY ANALYSIS

Based on ER 1165-2-121, an ability-to pay test should be applied to all flood control projects. The test determined the eligibility of the study area to quality for a reduction in the amount to be cost shared by the non-Federal interest. To qualify for a reduction, the results of both the benefit and income portions of the twofold ability-to-pay test must fall within the specified guidelines.

The benefits' test determines the maximum reduction, called the "benefits based floor" (BBF), in the level of non-Federal cost sharing for any project. The factor is determined by dividing the project B/C ratio by four. If the factor (expressed as a percentage) is less than the standard level of cost sharing, the project may be eligible for a reduction in the non-Federal share to this BBF. The WRDA 86 authorized cost share level for the Flood Protection project is 25 percent. The Recommended Plan's B/C ratio of 2.0 was divided by four to yield a BBF of .50 or 50 percent.

The income test determines qualification for the reduction calculated in the benefit step. Qualification depends on a measure of the current economic resources of both the project area and the State in which the project is located.

In accordance with factors released in Economic Guidance 96-4, the income index factors for the state of Texas and Brown County are 90.81 and 102.77, respectively. The Eligibility Factor (EF) for a flood control project is calculated according to the following formula:

$$EF = a - b_1 * (\text{State factor}) - b_2 * (\text{area factor}) \text{ where:}$$

$$a = 15.86794$$
$$b_1 = 0.06771$$
$$b_2 = 0.13543$$

Using the above formula, an EF of -4.2 was calculated for the city of Brownwood. An EF below zero indicates ineligibility for a reduction in construction cost sharing. As stated previously, a BBF factor for the investigated plan was calculated at 50 percent. To qualify for a reduction, the BBF factor must be less than the authorized level of cost sharing in accordance with ER-1165-2-121 paragraph 5a(2). The city of Brownwood does not meet the criteria for a reduction in construction cost since this project meets neither test. Therefore, the city of Brownwood must pay the currently authorized cost share level.

RECOMMENDATIONS

As indicated earlier, the primary planning objective for this feasibility level investigation was to determine the most economically and environmentally feasible plan to substantially alleviate the flooding problems within the Pecan Bayou watershed within the city of Brownwood.

The National Economic Development Plan (NED) identified in this investigation would consist of 15,680 feet of hydraulic channel improvement of Willis Creek within the city of Brownwood. The improvement would consist of reshaping the existing channel into a grass-lined trapezoidal channel with side slopes of 1 vertical to 3.5 horizontal with a bottom width of 40 feet with pilot channel. The channel depth would vary between 4 and 11 feet deep with the top varying between 40 to 135 feet wide. A diversion channel will be constructed approximately 1200 feet downstream of 14th Street Bridge to the 4th Street Bridge. The improvement will also require box culvert modifications to the 14th Street Bridge and 4th Street Bridge, side slope modifications at Austin Avenue Bridge, and some storm drain and utility relocations. Riprap will be placed at the bridge approaches for erosion protection. Environmental mitigation measures would consist of bypassing several oxbows and allowing them to serve as wildlife habitat and wetlands. Approximately 96 acres of reforestation will be undertaken to replace the habitat removed by the channel excavation.

CONCLUSIONS

The following conclusions and recommendations are made in connection with the study findings of these investigations:

1. A significant need for a local flood damage reduction project within the Willis Creek, Brownwood, study area exists. This plan would reduce expected annual damages of by 92 percent; eliminate all damages caused by the 10 percent ACE event and nearly 90 percent of the damages caused by the 1-percent event.

2. The overall flood damage reduction plan would have estimated first costs of $7,961,900, annual cost of $572,794, annual net benefits of about $314,820, and a benefit-to-cost ratio of 1.6.

3. The city of Brownwood was identified as the local sponsor for construction of the project. Federal and non-Federal cost apportionments for the Recommended Plan were estimated at $3,980,958 (50%) Federal and $3,980,958 (50%) non-Federal.

4. The Recommended Plan will cause no significant environmental impacts within the study area. A Finding of No Significant Impacts (FONSI) has been prepared and is included herein. Distribution of this report, including the FONSI, was made to the public for review on July 23, 2001.

RECOMMENDATIONS

I offer the following recommendations:

1. The flood damage reduction measures identified as the Recommended Plan for the Willis Creek, Brownwood, study area be authorized for construction.

2. Prior to project implementation, the non-Federal sponsor shall enter into a binding agreement with the Secretary of the Army to perform the items of local cooperation, as specified in this document.

3. This recommended project be converted from the General Investigations Program authority to the Continuing Authority Program authority due to the project cost, size, and scope. This will allow for a more timely implementation of the project.

The above recommendations contained herein reflect the information available at this time and current Departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of a national Civil Works construction

program nor the perspective of higher review levels within the Executive Branch. Consequently, the recommendations may be modified before they are transmitted to the Congress as proposals for authorization and implementation funding. However prior to transmittal to the Congress, the sponsor, the State, interested Federal agencies, and other parties will be advised of any modifications and will be afforded an opportunity to comment further.

_____

City of Brownwood

_____

Gordon M. Wells
Colonel, Corps of Engineers, Fort Worth District
Commander and District Engineer

LIST OF PREPARERS

The individuals who were primarily responsible for contributing to the preparation of the Interim Feasibility Report are listed below.

List of Preparers

NAME	DISCIPLINE	STUDY ROLE
Thomas Vogt	Project Manager	Project Management
Eli Kangas/Jason Foltyn	Lead Planner	Report Preparation
Craig Loftin	Hydrology and Hydraulics	Hydrologic and Hydraulic Analysis
Lanora Wright	Economics	Economics Analysis
Kenneth McCleskey	Geotechnical	Geotechnical Design Analysis
Larry Mendoza	Civil Engineering	Civil Design Analysis
William Sanner	Structural Engineering	Structural Design Analysis
Blake Bryant	Realty Specialist	Real Estate Analysis
Hank Jarboe	Environmental Resources	Environmental Assessment Analysis
Steve Austin	Cultural Resources	Cultural Assessment
Wayne Elliott	Environmental Design	HTRW Analysis
Jim Sears	Cost Engineering	Cost Estimating
U.S. Fish and Wildlife	Environmental Assessments	Coordination Act Report

FINDING OF NO SIGNIFICANT IMPACT
Local Flood Protection Project (Section 205)
WILLIS CREEK, BROWNWOOD, TEXAS

Willis Creek originates about five miles southwest of Brownwood, Texas, and flows generally north and then east, passing through the southern portion of Brownwood, to its confluence with Pecan Bayou southeast of the city. The watershed has a drainage area of 28.4 square miles. At the request of Brownwood, the U.S. Army Corps of Engineers initiated studies under the authority of Section 205 of the Flood Control Act of 1948, as amended, to evaluate potential solutions to flooding problems associated with Willis Creek within the city limits of Brownwood.

Structural and nonstructural alternatives that were evaluated for consideration included flood regulation, flood forecasting and warning, flood proofing, flood plain management, permanent relocation, detention ponds, levees, hydraulic channels, and bridge relocations. The hydraulic channel was the only alternative that proved economically, technically, and socially feasible. Hydraulic channels with bottom widths of 10, 20, 45, and 60 feet were evaluated for further consideration. A 40-foot bottom width hydraulic channel alternative approximately 15,680 long was incrementally selected as the Recommended Plan.

The proposed plan for Willis Creek local flood damage reduction would be a hydraulic channel improvement approximately 15,680 feet long. The improvement would begin near Asbury Street, and extend approximately 6,400-feet downstream (about 1,200 feet downstream of 14th Street.) At this point, a diversion channel would be excavated across an open field, reconnecting to Willis Creek about 2,000-feet downstream (approximately 500-feet upstream of 4th Street). From the point, the improved channel would proceed 7,880-feet to the downstream terminus of the plan. The improved channel, including the diversion channel would have average bottom width of 40-feet, with side slopes of 1 vertical on 3.5 horizontal. The proposed plan would require modifications to two box culvert crossings. The four existing 8-foot by 6-foot culverts at 14th Street would be replaced with eight 10-foot by 10-foot culverts. Three 10-foot by 8-foot culverts would be added to the four existing 10-foot by 8-foot culverts on 4th Street. Riprap would be placed at the bridge approaches for erosion protection. Approximately 545-feet of different types of storm drain (reinforced concrete and galvanized pipe) would be extended. In addition, approximately 1,581-feet of various sanitary sewer, water, and gas utility lines would be relocated.

This plan would reduce expected annual damages of by 92 percent; eliminate all damages caused by the 10 percent ACE event and nearly 90 percent of the damages caused by the 1-percent event.

The Recommended Plan and the other feasible alternative were evaluated for impacts to cultural resources and the natural and human environment. As proposed, The Recommended Plan would have no adverse affects on cultural resources, beneficial affects to the human environment by providing protection from floods and adverse affects to the terrestrial and aquatic ecosystem of Willis Creek. It was estimated that The Recommended Plan would adversely affect 15.9 acres of old field and 31.7 acres of forested habitat. All aquatic habitat within the reaches of the creek that are proposed for construction would be lost as a result of the proposed project. An environmental mitigation plan would be implemented in an area adjacent to the study site and would involve preservation of base water flow in several creek bends and conversion of low quality wildlife habitat old fields to high quality wildlife habitat containing hard mast producing trees and fruit bearing shrubs, and some pool/riffle. Specific details of the mitigation plan would be provided when the draft Coordination Act is received from the Fish and Wildlife Service.

The possible consequences of the recommended plan have been considered in accordance with Sections 404 and 401 of the Clean Water Act. The Recommended Plan would result in adverse affects to approximately 13,336 linear feet of channel and 9.1 acres of waters of the United States. On the basis of the guidelines set forth in ER 1105-2-100 and 40 CFR Part 230 for a Section 404(b)(1) evaluation (Guidelines for Specification of Disposal Sites for Dredged

or Fill Material), the recommended plan for the Willis Creek Flood Damage Reduction Project would be specified as complying with the inclusion of appropriate and practical conditions to minimize pollution or adverse effects to the aquatic ecosystem and to implement and abide by the mitigation plan in this document. The proposed project is in compliance with Section 401 of the Clean Water Act.

Based upon the Environmental Assessment and results of coordination, I have concluded that the proposed action would not have a significant adverse affects on the human or natural environment. Consequently, construction of the proposed project would not constitute a major Federal action of sufficient magnitude to warrant the preparation of an Environmental Impact Statement.

_____ _____

Date

Gordon M. Wells
Colonel, Corps of Engineers
District Engineer